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PHOTOSTRESS TO ANALYZE BEHAVIOR OF
AN AFT SKIRT TEST SPECIMEN Final
Report (Alabama Univ.) 73 p

FINAL REPORT

EXHIBIT "A"

USE OF PHOTOSTRESS TO ANALYZE BEHAVIOR OF
AN AFT SKIRT TEST SPECIMEN

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Prepared for

NASA/MSFC
through the University of Alabama in Huntsville

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May 1994

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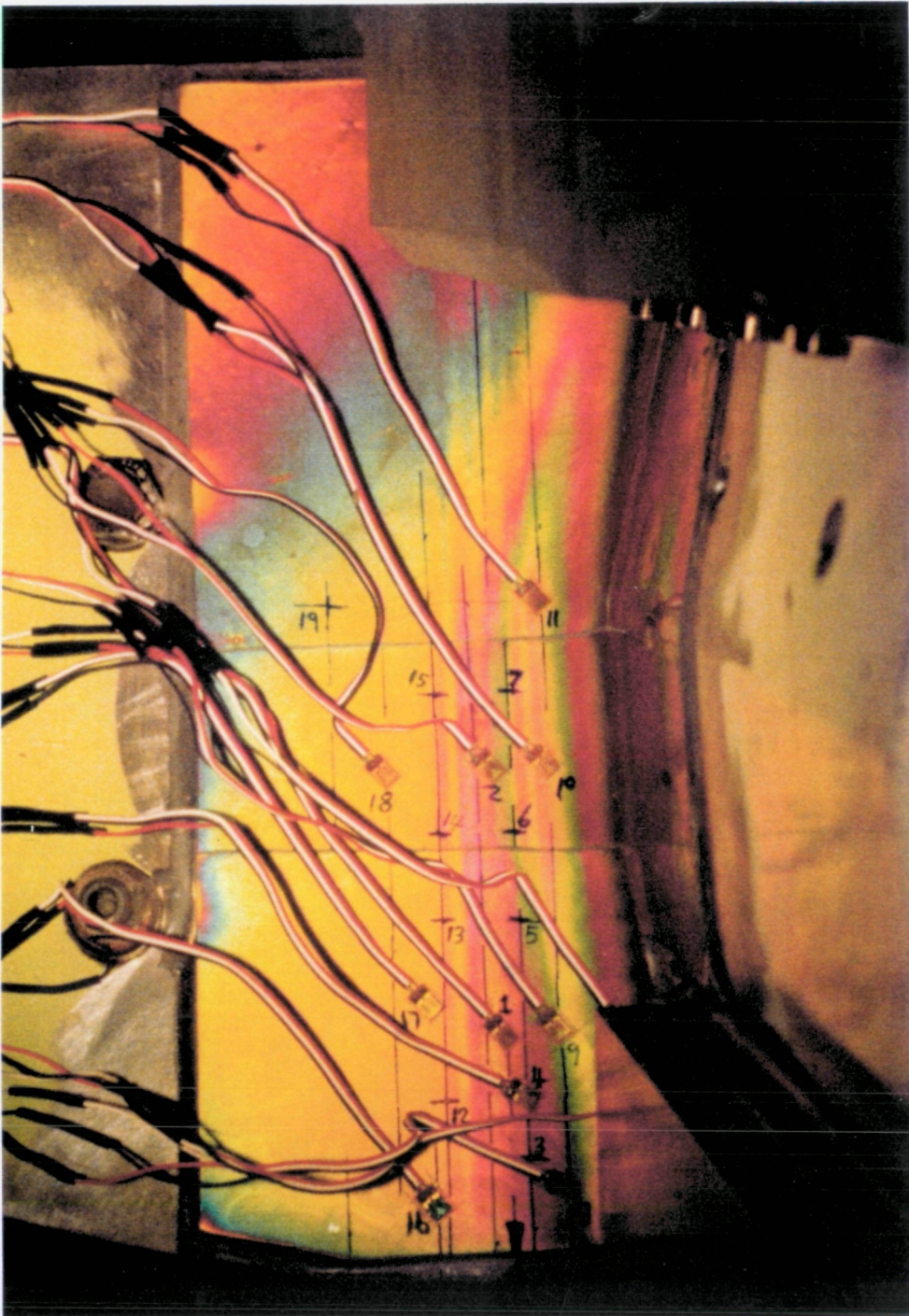
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FRONTISPIECE



Lower Weld
Aft Skirt
Solid Rocket Booster
70% Design Limit Load

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ABSTRACT

Strains at twenty-one selected points in the critical lower weld region of a aft skirt of a solid rocket booster of the shuttle were measured using photoelastic coatings and stress separator gages. Data were taken at loads of 5, 14, 20, 28, 42, 56, and 70 percent of the design limit load.

Results indicate that general yielding occurred in the weld metal and for a short distance outside the fusion boundaries on either side of the weld metal. The fusion boundaries did not yield at the 70 percent load. Slight non-linearity in the load-strain curves were observed at several points above the 20 percent load level. Maximum measured strains occurred at points in the forged metal of the holddown post along a line 0.50 inches from the centerline of the weld. Maximum shearing strains within the area covered by the photoelastic coating occurred at points approximately 0.33 inches to the right of the weld centerline near points 6 and 7 and lying along a yellow vertical line extending from just below point 6 to point 11. No data were taken along this line but it may be observed in Photograph 16 and in the FRONTISPIECE photograph.

Photoelastic coatings were shown to be an excellent method to provide the whole field strain distribution in the region of the critical weld and to enhance the overall understanding of the behavior of the welded joint.

I. INTRODUCTION

Previous work using Photostress on gas tungsten arc welded (GTAW) heat treated tensile specimens of 2219-T87 base metal and 2319 weld metal indicated that behavior of the joint can be highly irregular and non-uniform (1,2,12). Welded joints 1.40 inches thick exhibited a totally non-uniform behavior through the weld thickness with the outside diameter (*OD*) side of the weld being much more ductile than the inside diameter (*ID*) side where (*OD*) and (*ID*) refer to the outside and inside diameters of the aft skirt of the solid rocket booster (*SRB*) respectively. It has been shown (12) that this difference in behavior through the weld is, in part, caused by procedures used when laying the weld bead.

Joints similar to those tested in references 1, 2, and 12 are an integral part of the aft skirt of the *SRB* of the shuttle. Since the ultimate safety factor for the lower portion of the weld is below the minimum required safety factor, a Photostress analysis of this lower portion was conducted in the vicinity of the weld (see Figure 1). The test program using Photostress was conducted in accordance with the project planning document entitled "Photostress Evaluation Requirements for AFT Skirt Test Article No. 4"(3).

Sketches of the reaction structure used for loading the test article are given in Figures 2 and 3. A sketch of the four test articles and their relative positions in the aft skirt are given in Figure 4. Photographs 1 through 10 show the test article at various stages of instrumentation and also show the equipment used for measuring strains. To illustrate variability of mechanical properties in the welded joint, Figures 5 and 6 show results from tensile tests conducted in 1992 compared with results obtained in 1993 from different lots

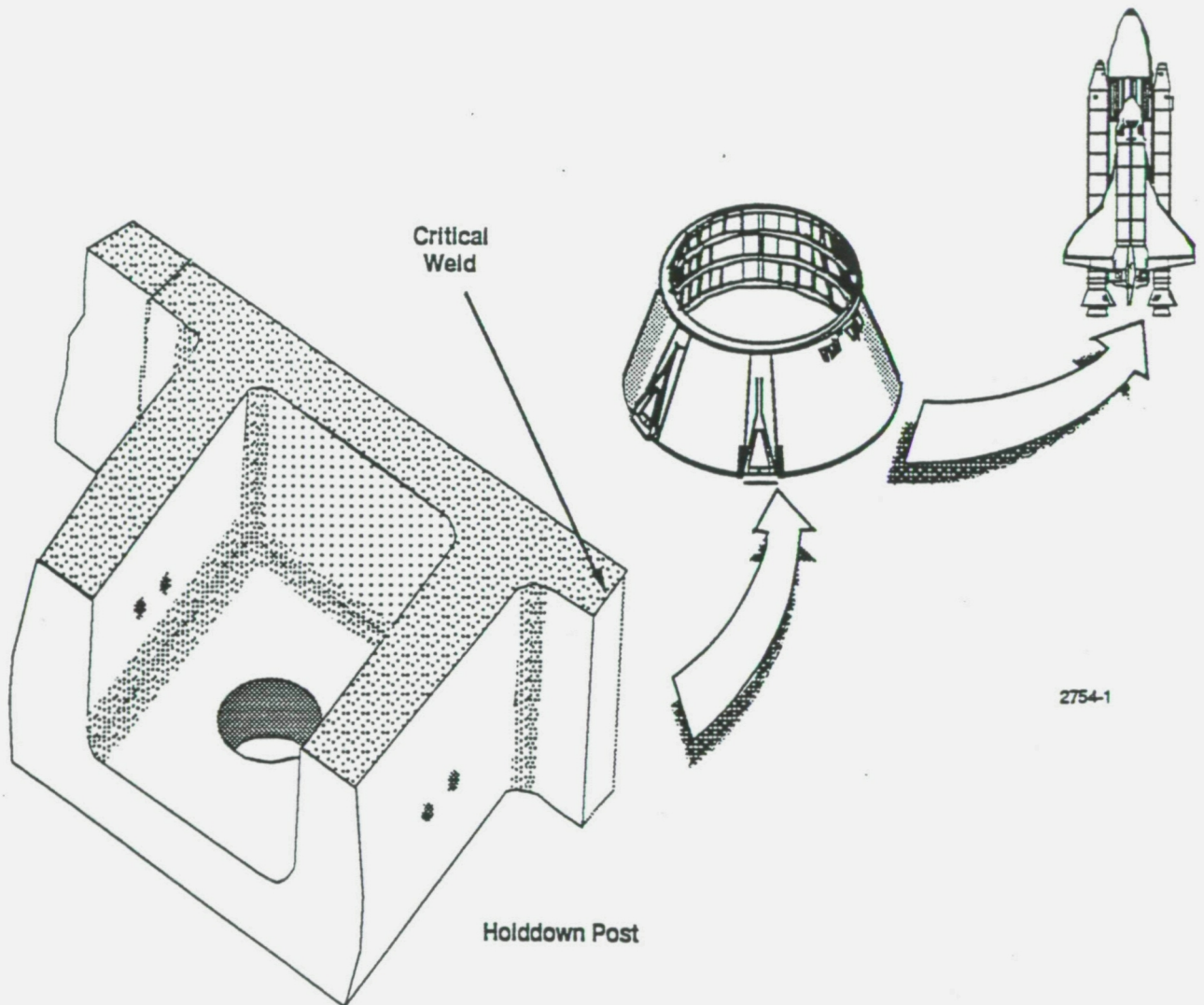


Figure 1. Critical Weld Region

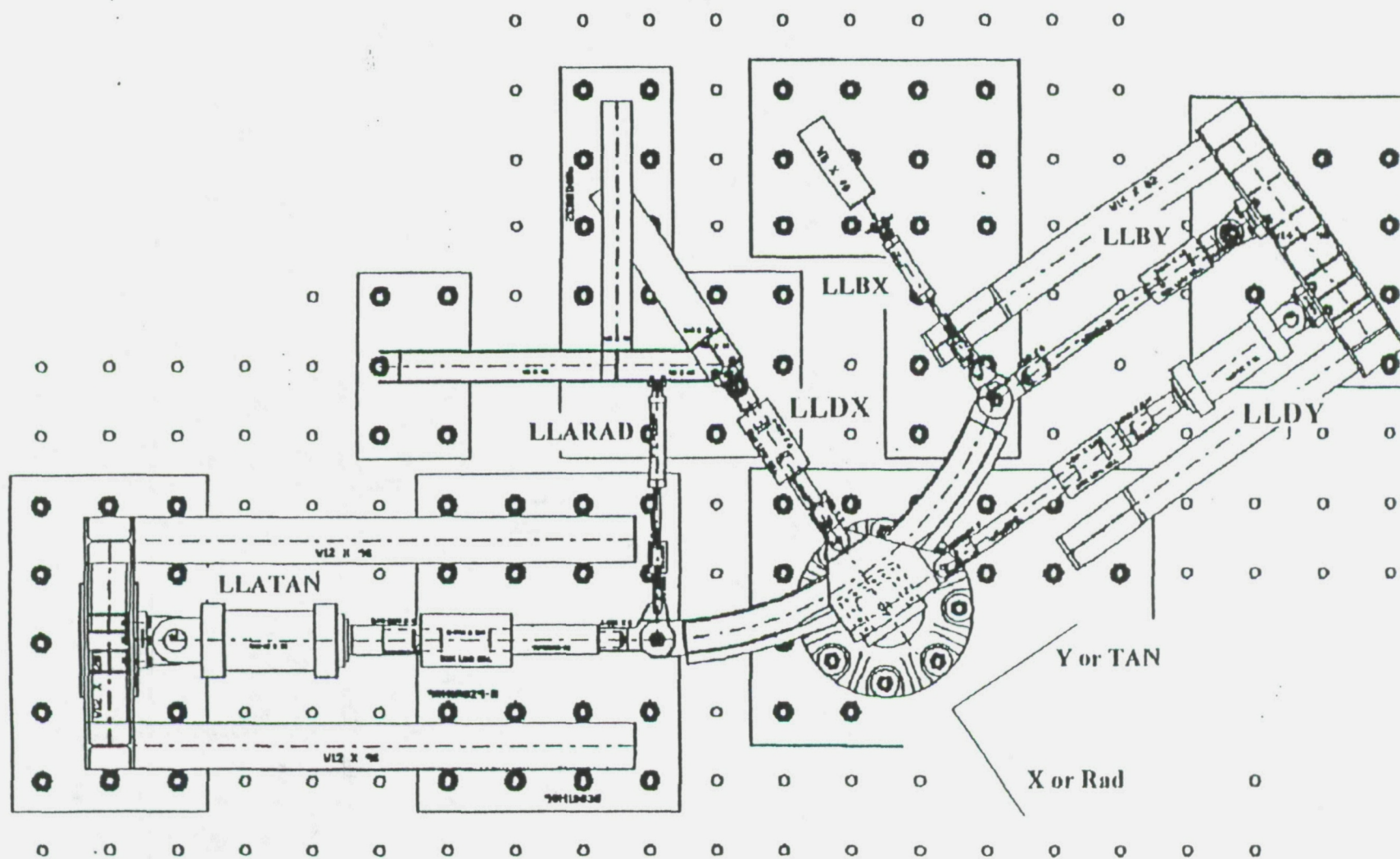


Figure 2. Test Setup, Top View

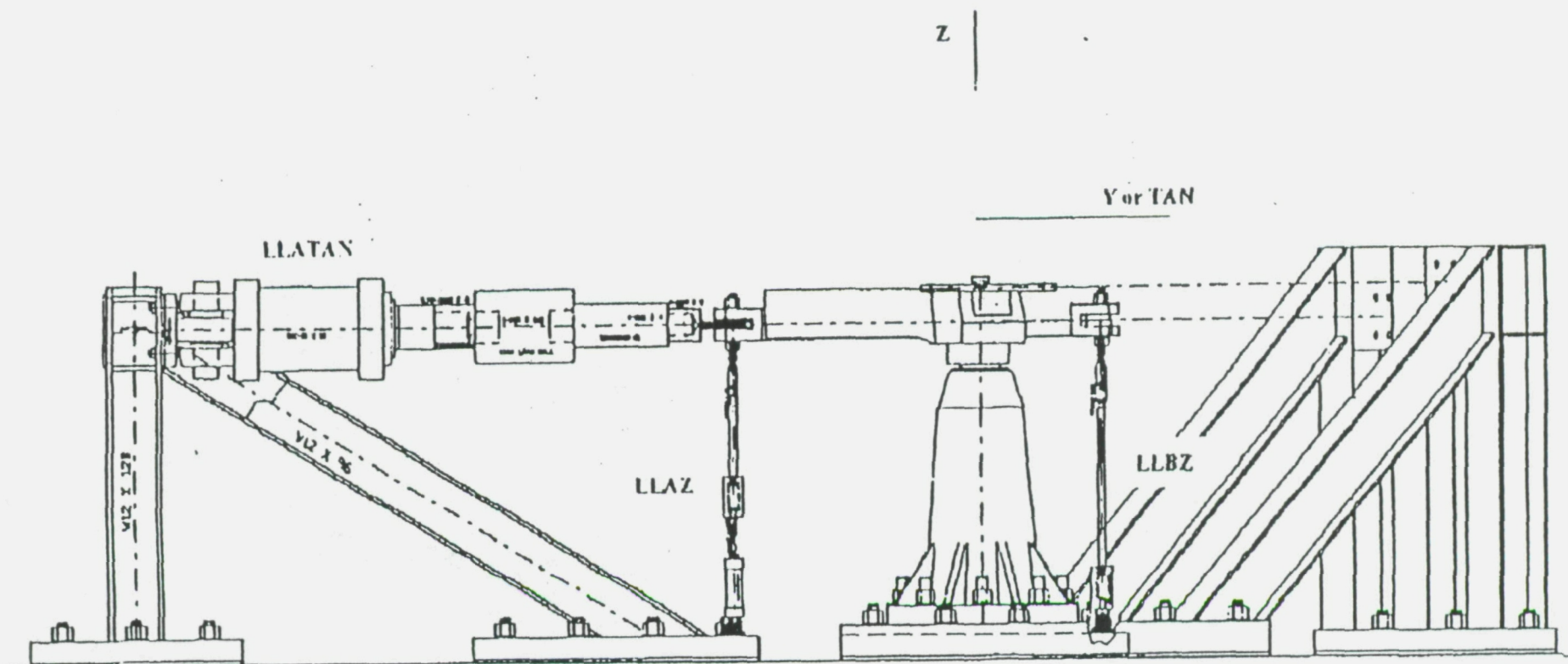


Figure 3. Test Setup, Side View

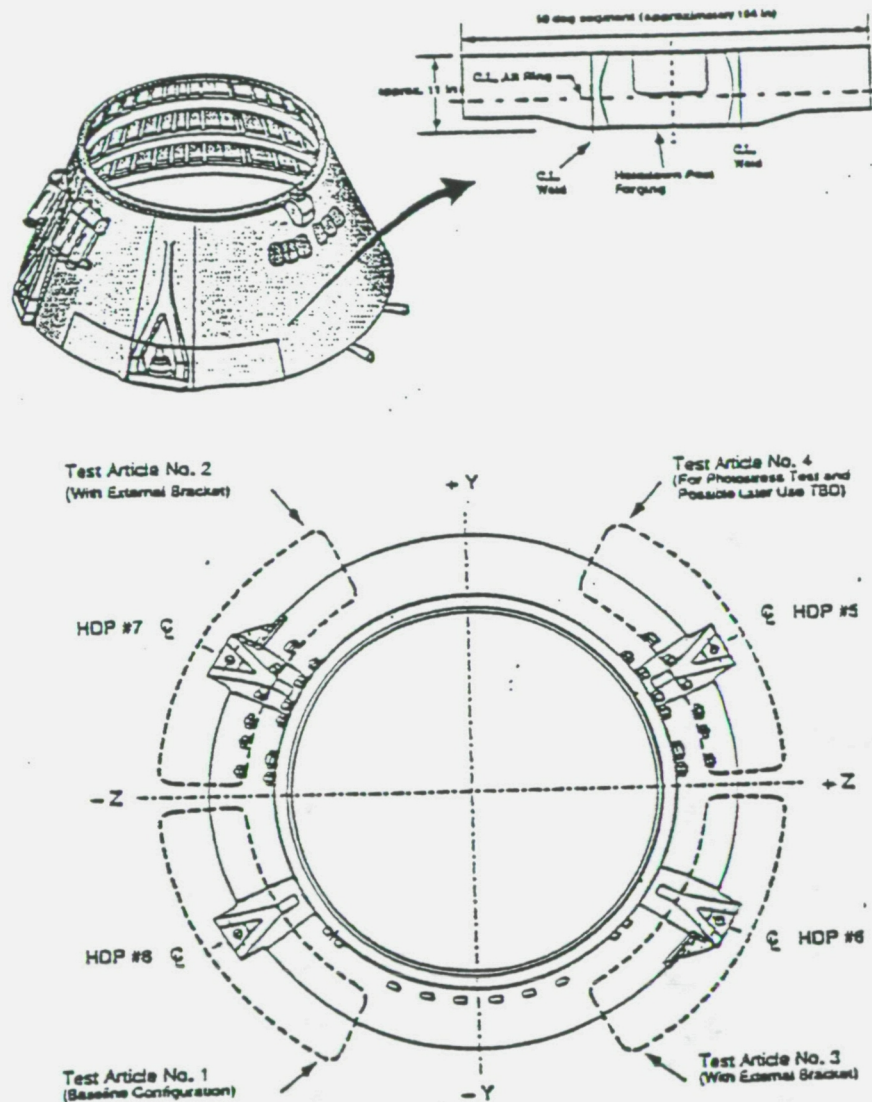


Figure 4. Locations of Aft Skirt Test Articles

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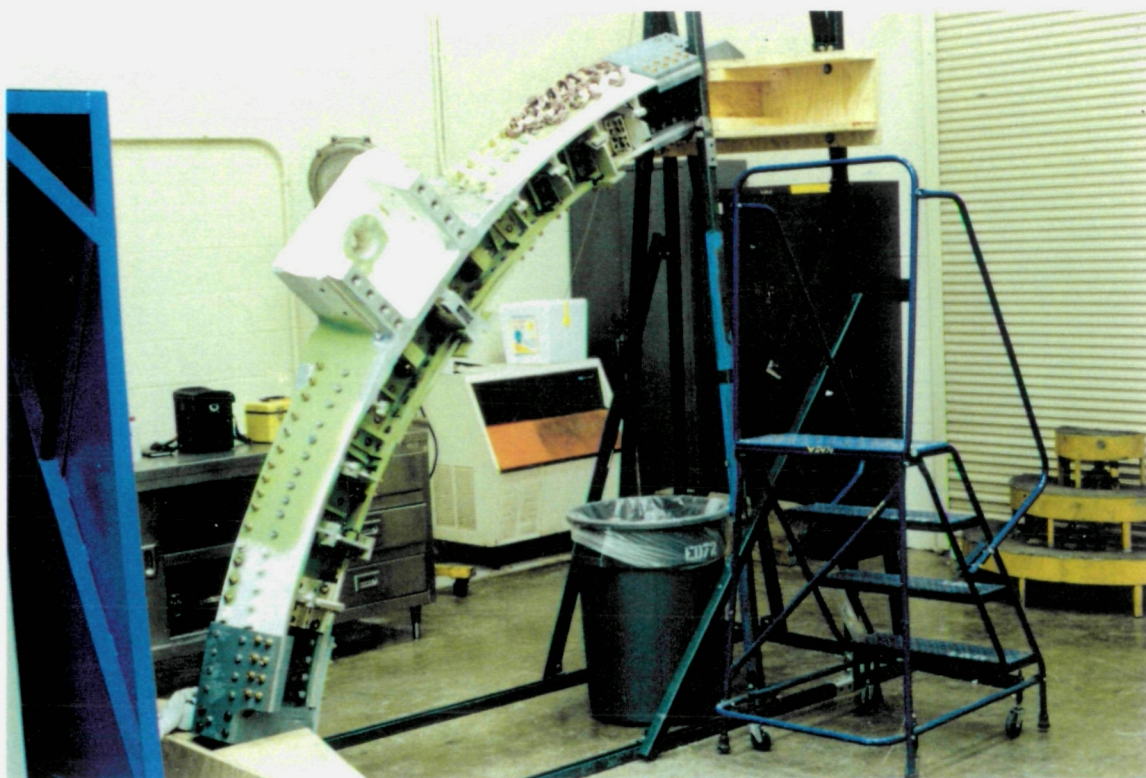


Photo 1. Test Article in Instrumentation Position

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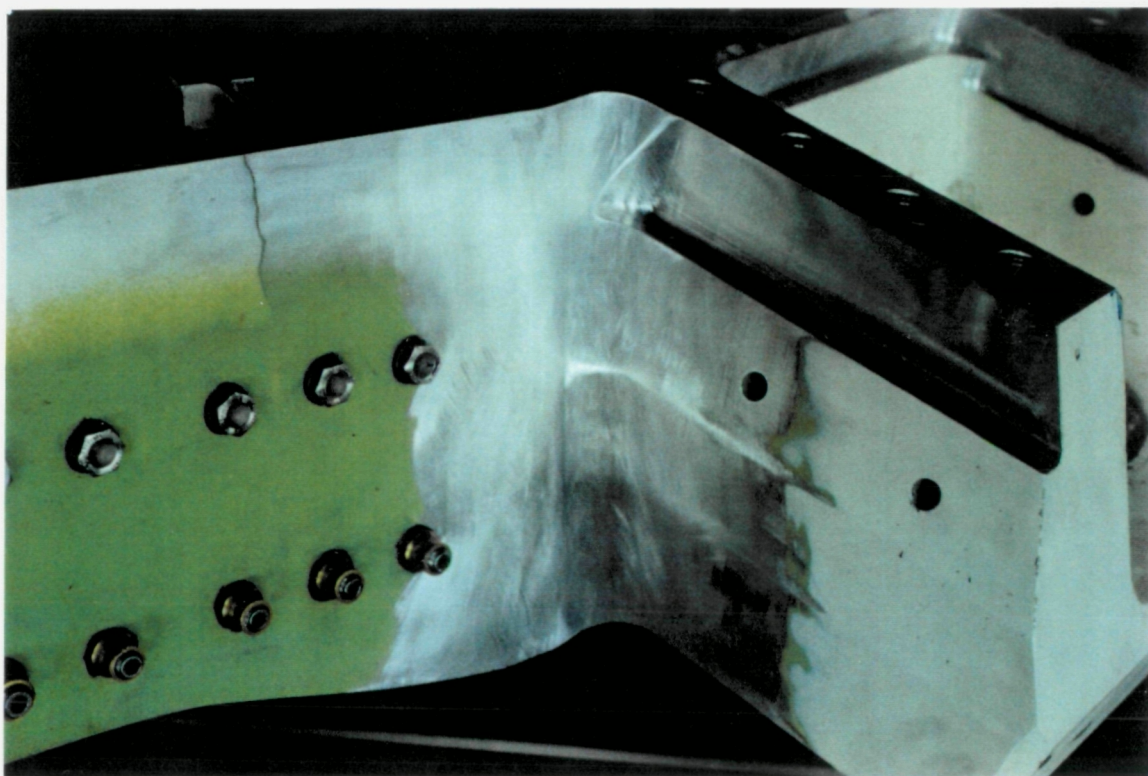


Photo 2. Weld Area Prepared for Instrumentation

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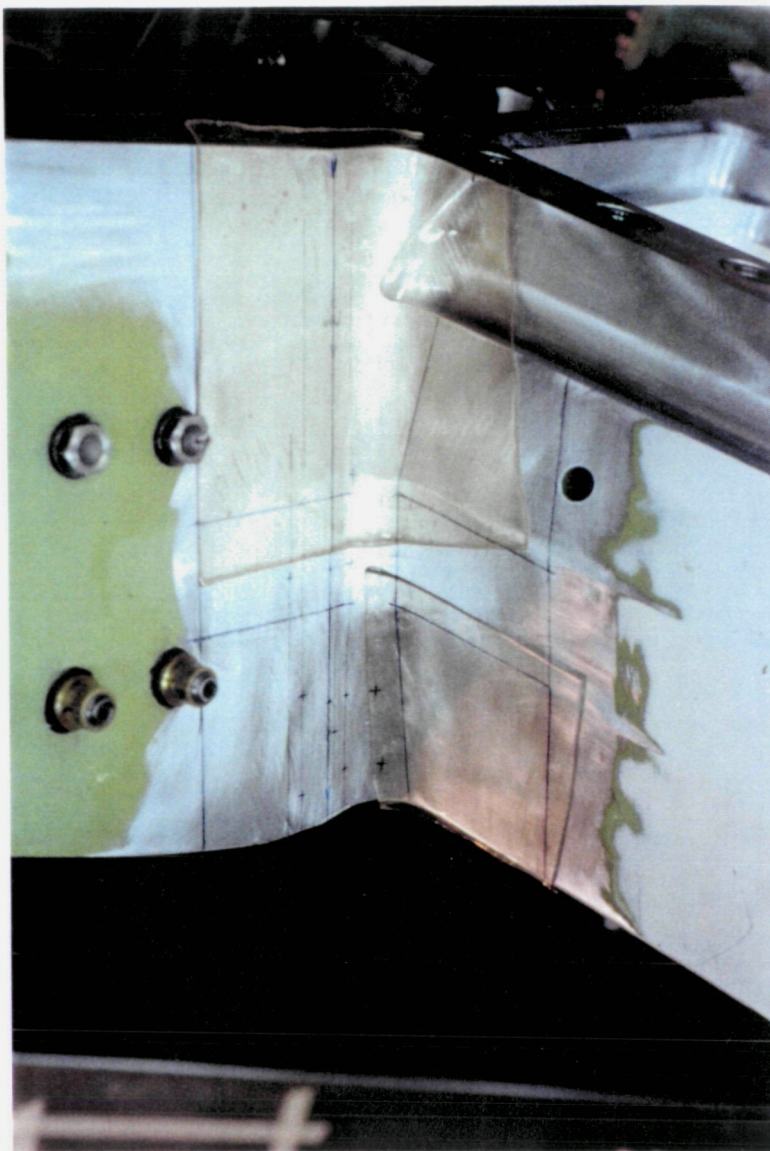


Photo 3. Contouring of Photoelastic Coating

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Photo 4. Coating Bonded to Area

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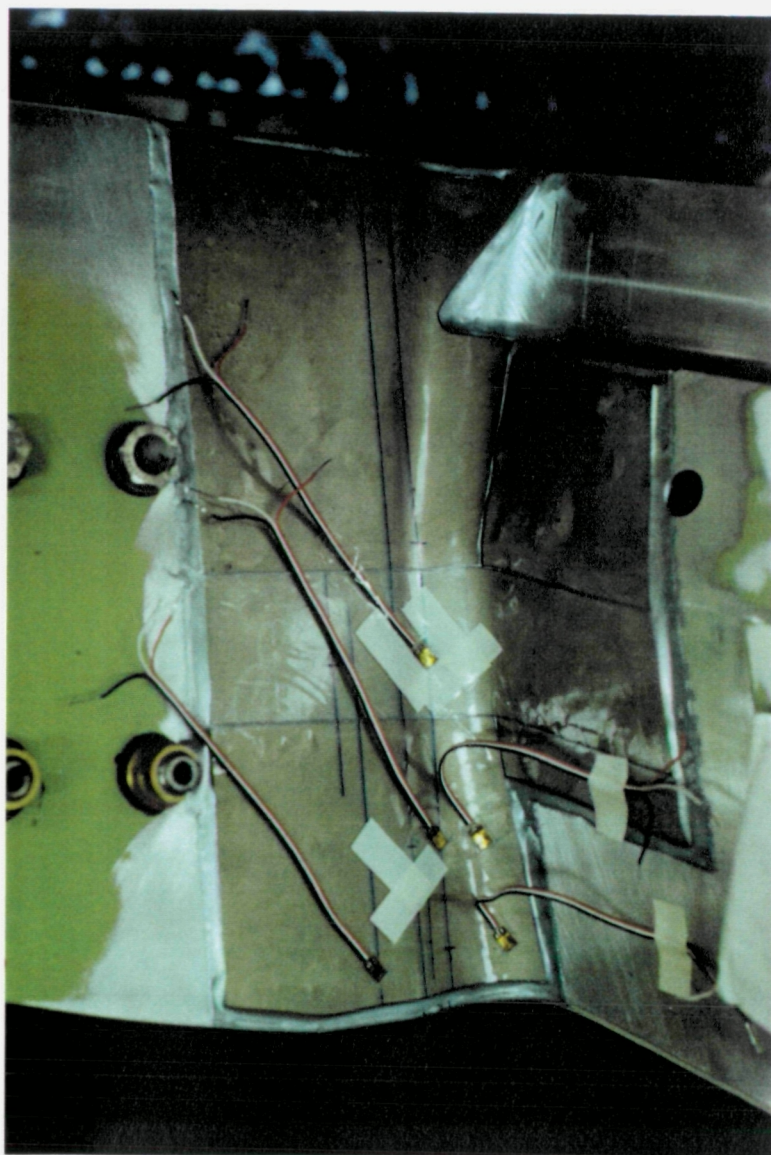


Photo 5. Attachment of Separator Gages

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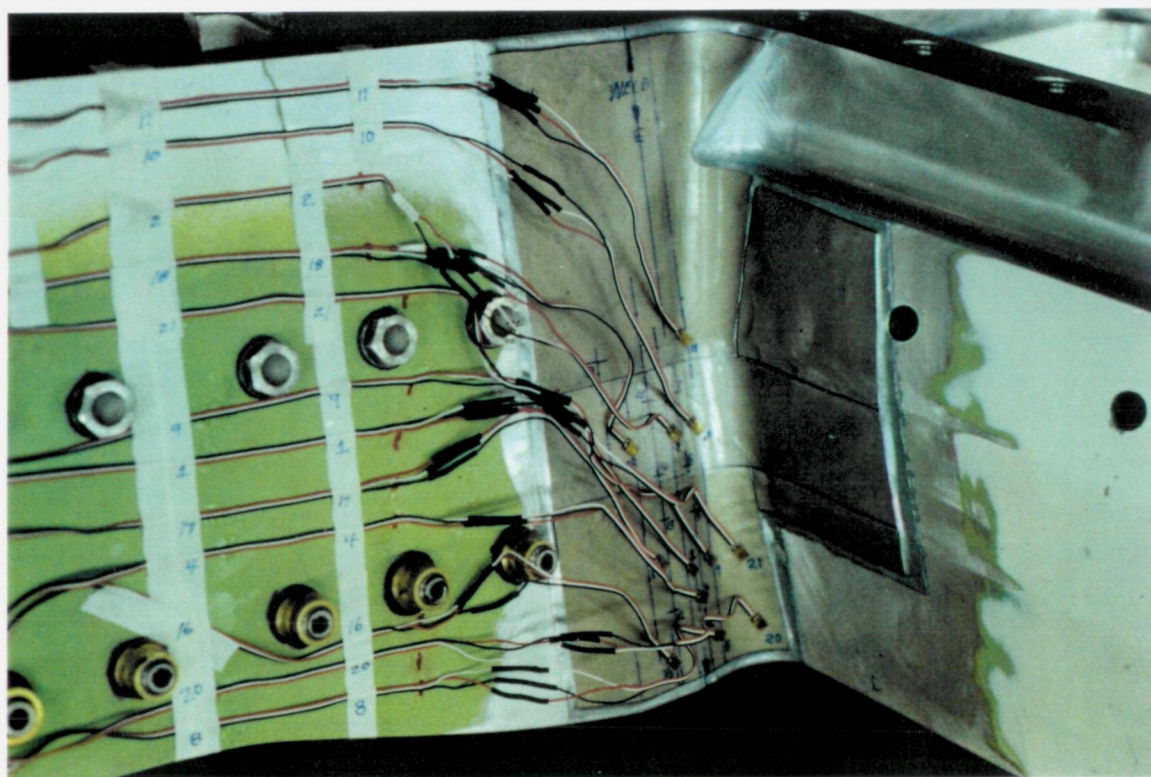


Photo 6. Complete Instrumentation of Coating

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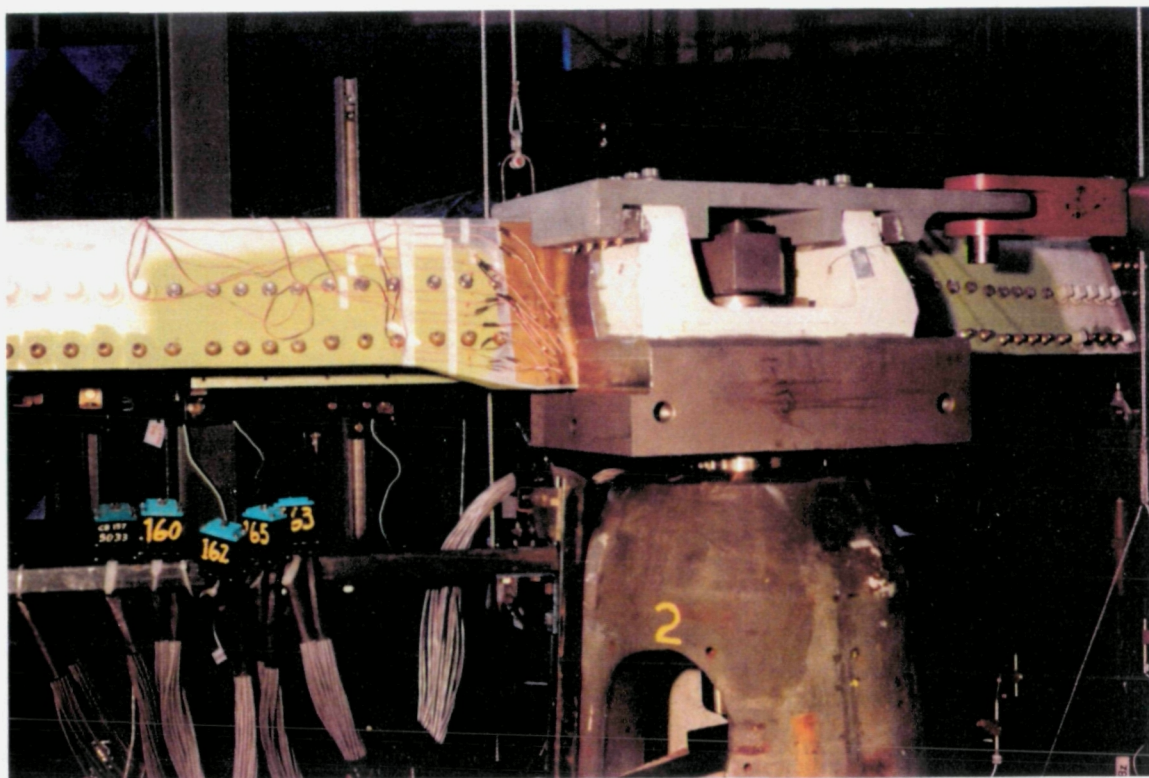


Photo 7. Test Article in Reaction Structure

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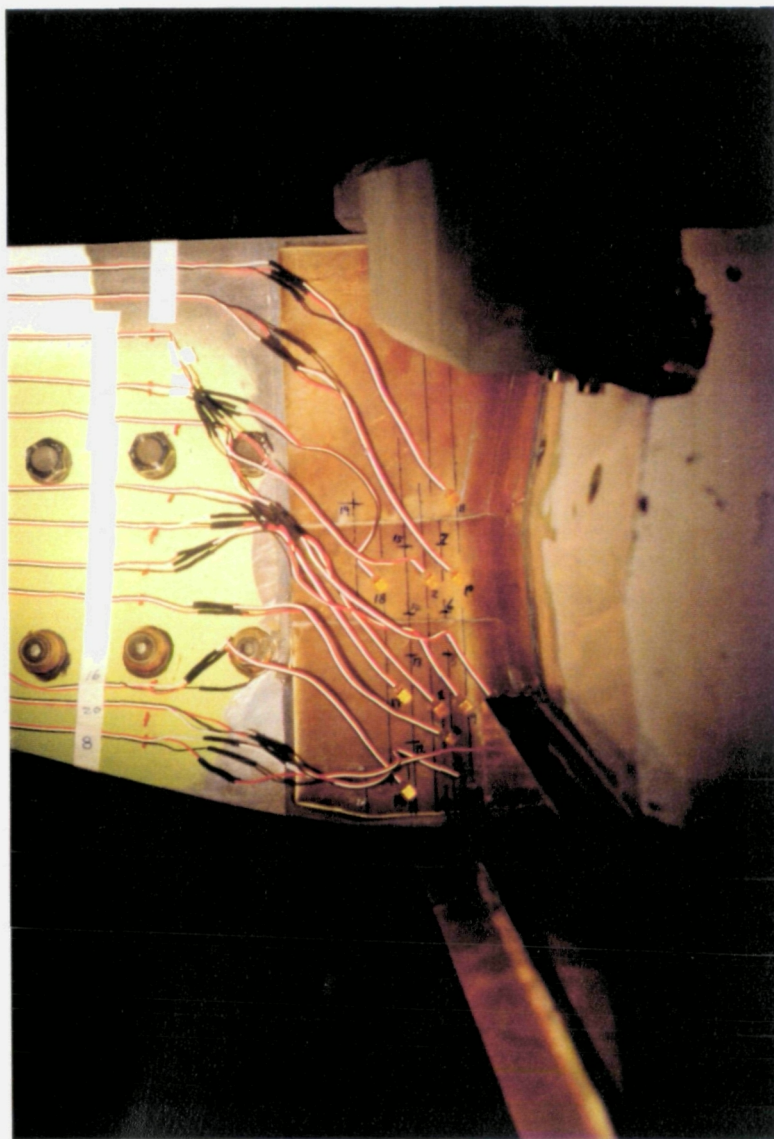


Photo 8. Coating Prior to Load Application

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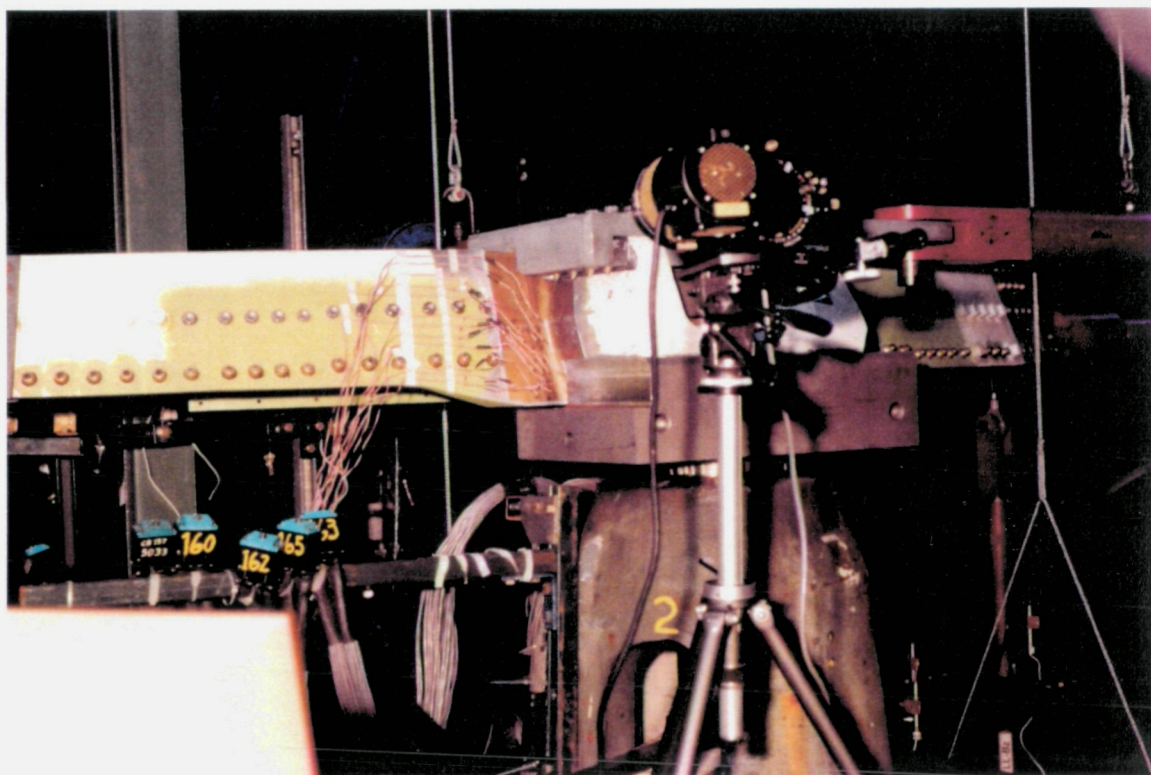


Photo 9. Polariscope in Position for Measurement

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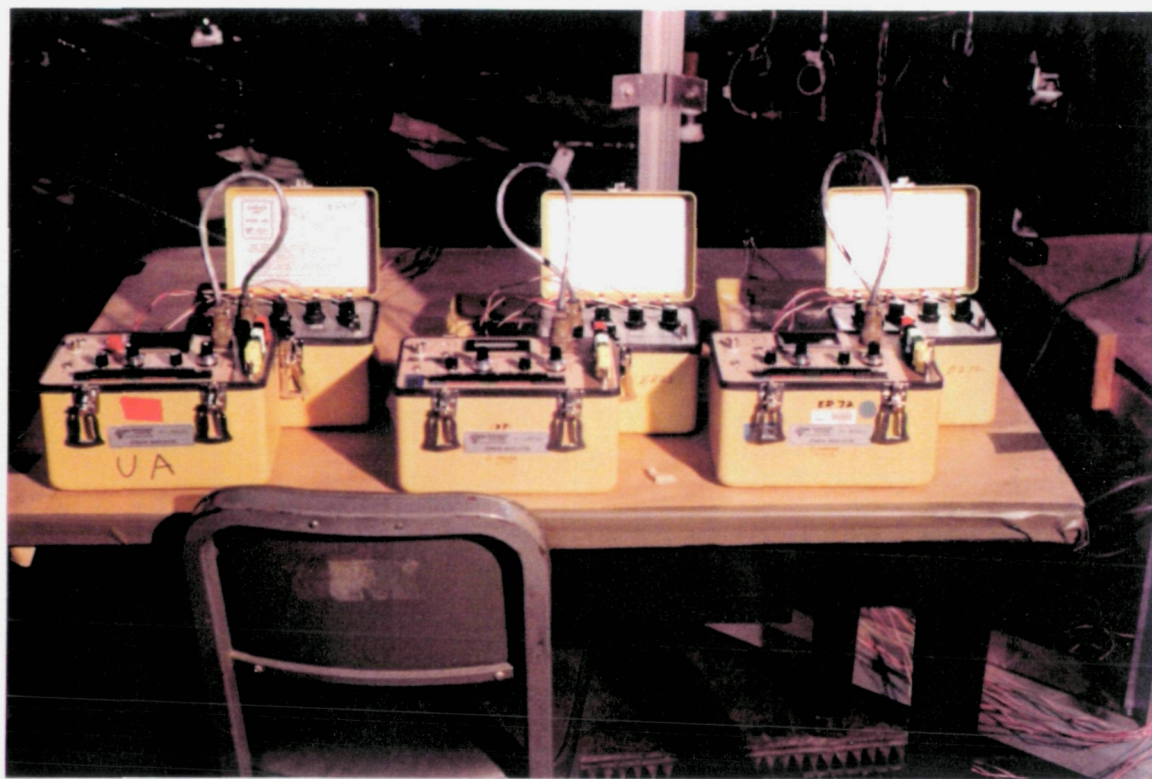


Photo 10. Instrumentation for Separator Gages

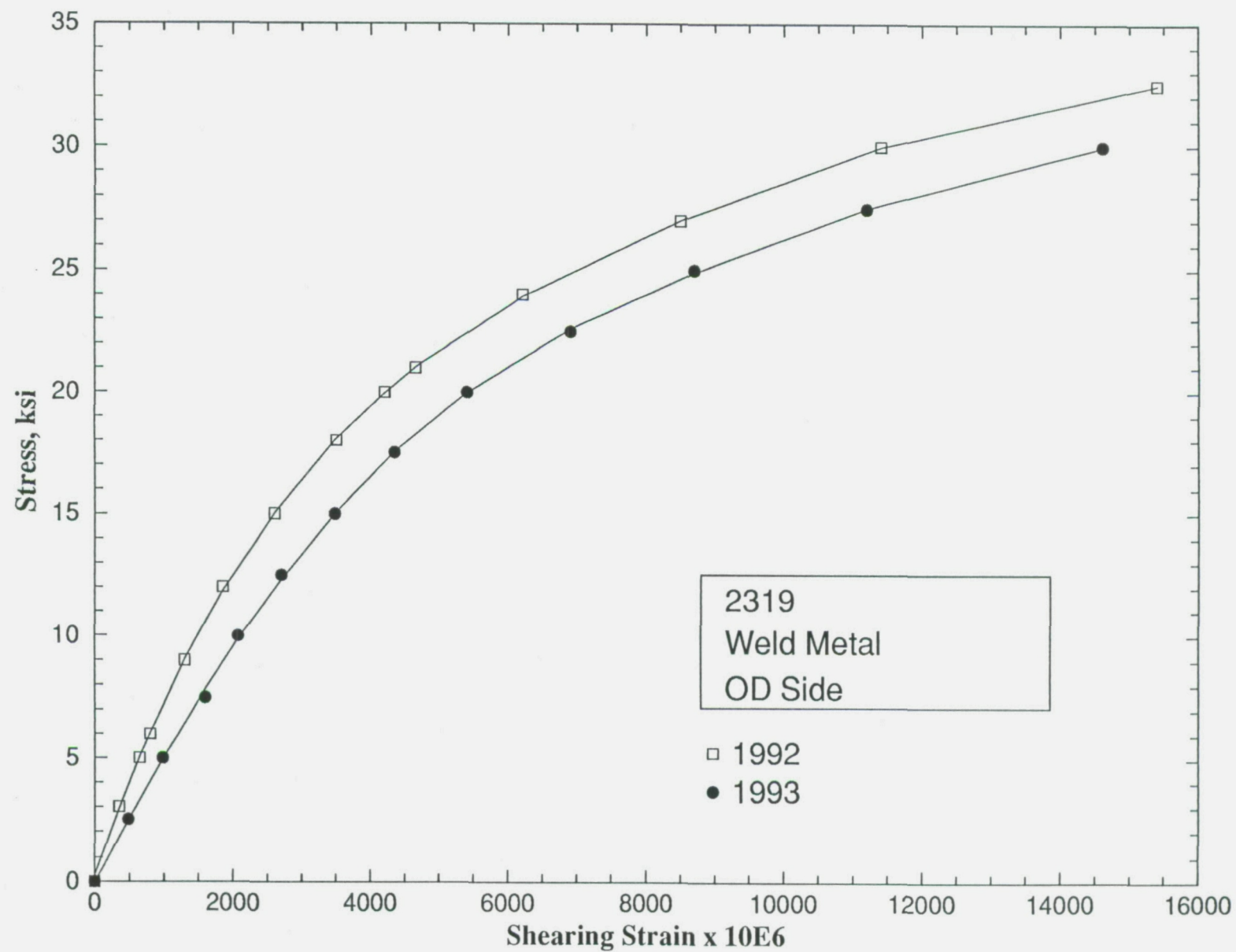


Figure 5. Variation in Mechanical Properties, Weld Metal

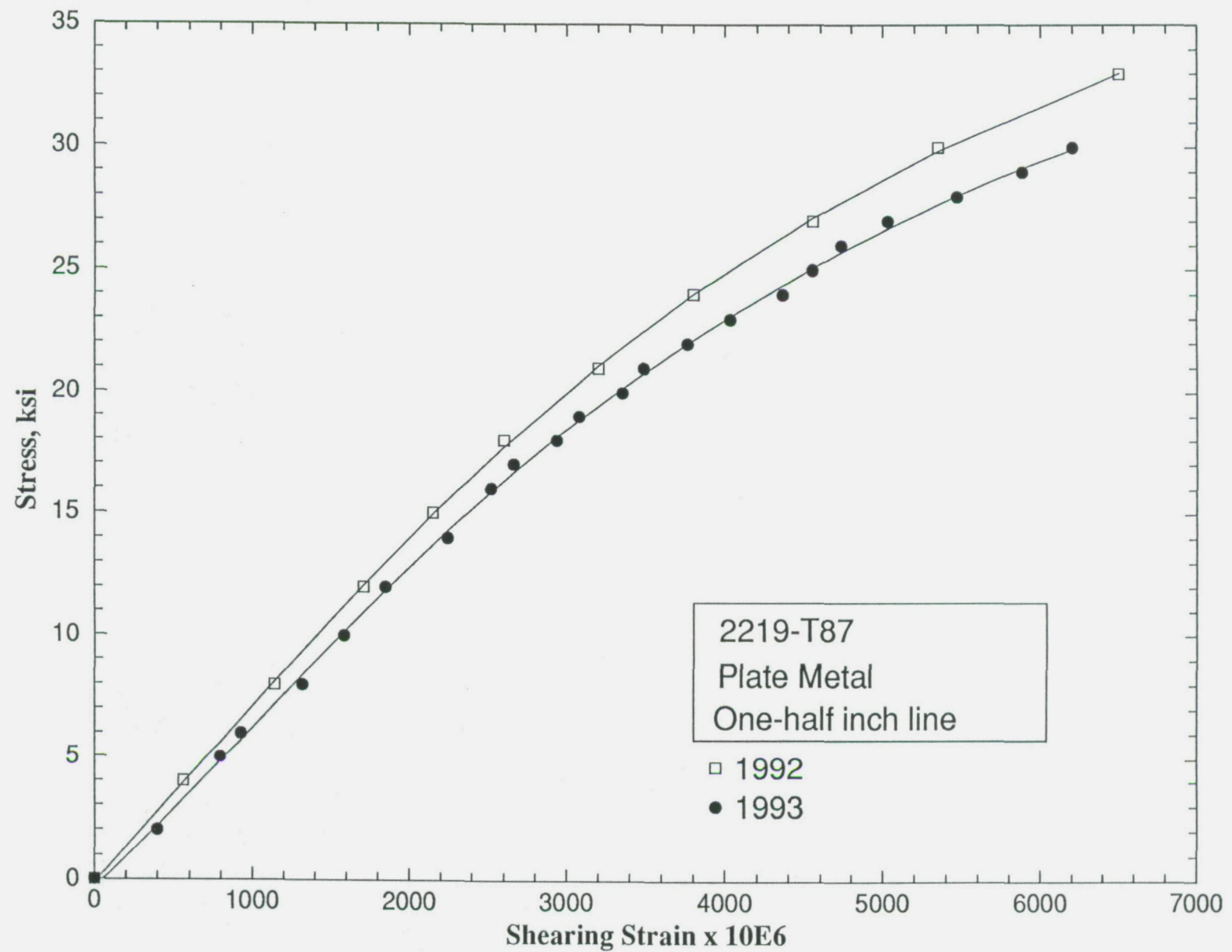


Figure 6. Variation in Mechanical Properties, Plate Metal

of welded joints. Note the rather large variation in strain for a given stress at the weld centerline and at a point one-half inch away from the weld centerline. Thus, results obtained from this test on the aft skirt should be viewed with due consideration of the variability in measured values between welds from two different lots.

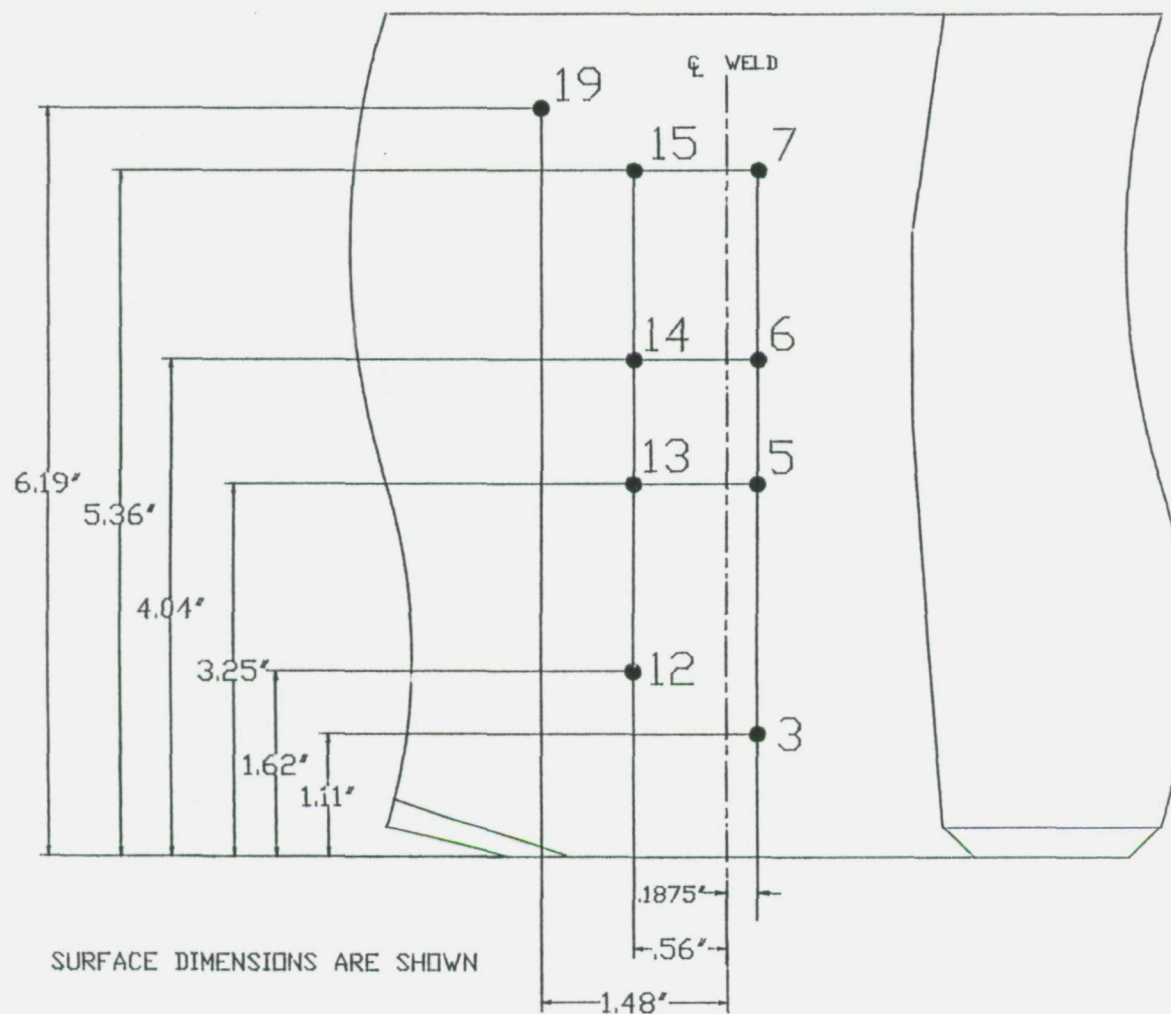
II. POINTS FOR DATA COLLECTION

Data were collected at points determined by J. P. Heflin which are shown in Figures 7 and 8. Figure 7 shows locations where only maximum shearing strains were measured using the photoelastic coating and Figure 8 shows points where separator gages were used along with the photoelastic coating to separate the principal strains. Vertical dimensions shown in these figures lie on the surface of the coating and were determined by dividing the vertical dimension in the xyz coordinate system by the cosine of the angle of inclination of the surface of the test article.

III. INSTRUMENTATION

The photoelastic coating was PL-1 plastic poured and contoured to the surface of the test article in five separate pieces which were needed to cover the double curvatures associated with the area of interest surrounding the welded joint. PC-1 adhesive was used to apply the coating to the test article. The average thickness of the coating was 0.0679 inches with a standard deviation of 0.00049 inches. The average fringe value for the coating was 1672 micro-inches per inch per fringe. Within $\pm$ two standard deviations, an accuracy of $\pm 1.5\%$ or ± 25 micro-inches per inch due to different coating thickness can be obtained.

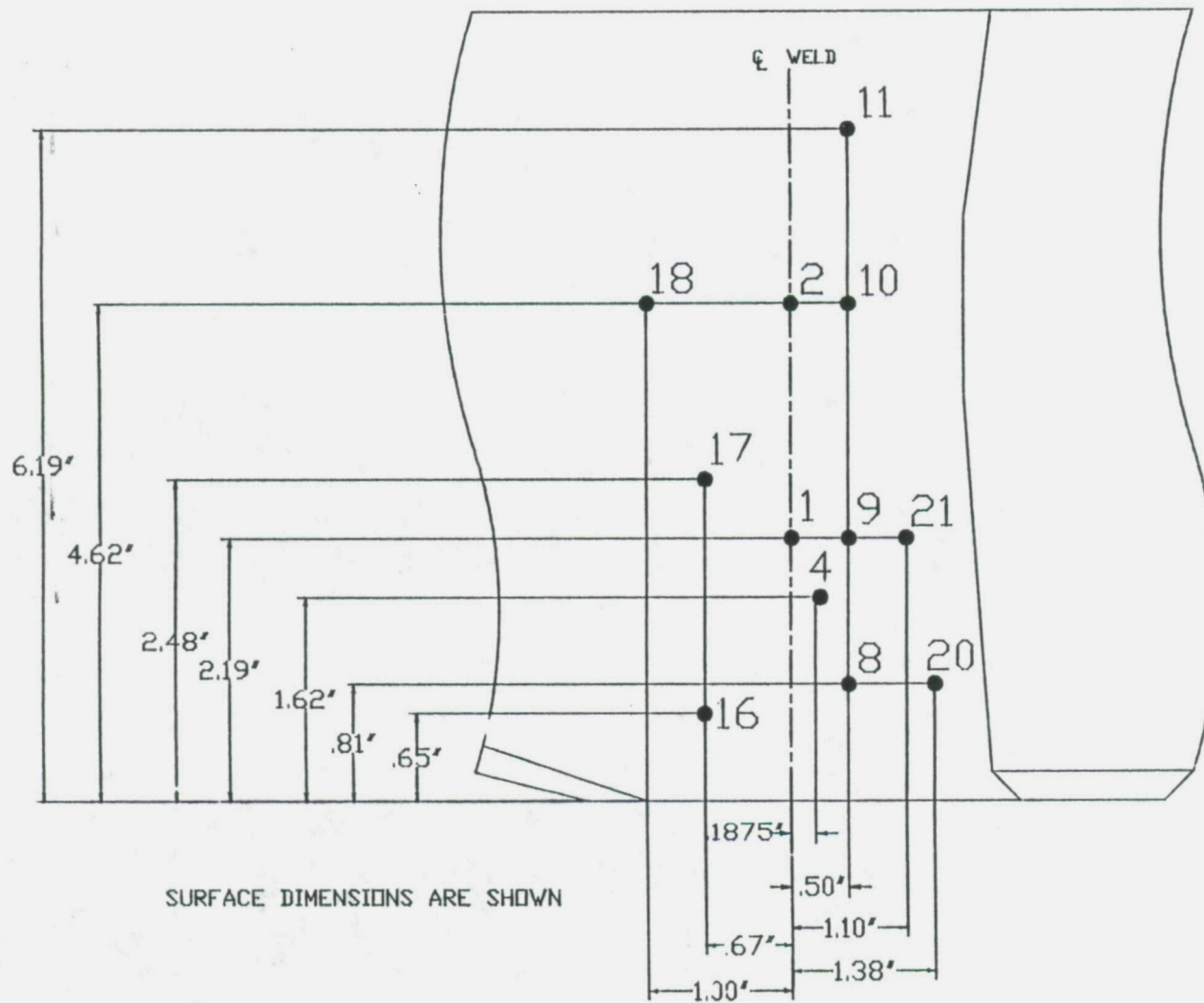
At those points indicated in Figure 8, separator gages were used to determine values



TA1 Instrumentation

- 3 = Strip Gage Element (S1127)
- 5 = Strip Gage Element (S1155)
- 6 = Strip Gage Element (S1167)
- 7 = Strip Gage Element (S1185)
- 12 = Uniaxial Gage (S1212)
- 13 = Uniaxial Gage (S1220)
- 14 = Uniaxial Gage (S1223)
- 15 = Uniaxial Gage (S1230)
- 19 = Uniaxial Gage (S1233)

Figure 7. Locations for Maximum Shearing Strains Only



TAI Instrumentation

- 1 = No Gage
- 2 = Strip Gage Element (S1172)
- 4 = Strip Gage Element (S1135)
- 8 = Uniaxial Gage (S1208)
- 9 = Uniaxial Gage (I214)
- 10 = Strip Gage Element (S1179)
- 11 = Strip Gage Element (S1199)
- 16 = Triaxial Gage (T1206)
- 17 = Triaxial Gage (T1217)
- 18 = Triaxial Gage (T1226)

Figure 8. Locations for Separator Gages

of the maximum and minimum principal strains at those points. These gages were type PSG-01-13 and were bonded to the surface of the plastic using M-Bond 200 adhesive. Gage factors are given to within $\pm 5\%$ for separator gages. Thus, there is a potential error of approximately $\pm 5\%$ in measuring the strains using the separator gages. Strains from the separator gages were recorded using P-3500 static strain indicators and model 330 interface modules.

Maximum shearing strains were recorded using a reflective polariscope, a uniform field compensator, a digital printer/recorder, and a 35 mm camera with Kodak Ektar 1000 color film. In general, accuracy for measuring fringe orders is within $\pm 5\%$ of a fringe which, for this work, represents ± 84 micro-inches per inch shearing strain. Therefore, considering the variability in thickness of the coating and the accuracy to which fringe orders may be measured, the error in measuring shearing strains at a given point could be as much as ± 109 micro-inches per inch. It is unlikely, however, that the maximum possible error was present in the individual readings.

In addition to the maximum shearing strain, the photoelastic coating technique also provides the angle locating the principal coordinates. With the X axis defined as being tangent to the upper surface of the test article, the direction of the principal strains never deviated more than ± 6 degrees from the X axis. Therefore, for practical purposes, the principal coordinates are approximately perpendicular and parallel to the weld.

Design parameters for the test article specified that a maximum shearing stress of 8,500 micro-inches per inch be measured (3). During the test, a maximum shearing strain of

approximately 4,300 micro-inches per inch was measured. Therefore, approximately 50.6% of the capability of the photoelastic coating was used during the test. This resulted in the isochromatic fringes being spaced farther apart than they would have been if the full capability of the coating had been used.

All coatings, gages, adhesives, and equipment were obtained from Measurements Group, Inc., Raleigh, NC. (4,5,6,7,8,9,10,11)

IV. CONSIDERATIONS FOR USE OF SEPARATOR GAGES

Separator gages are designed basically for use on photoelastic coatings bonded to elastic material. For their use, it is intended that the test article be loaded to the maximum load during which time the maximum shearing strains are measured in the coating as the test article deforms elastically. Then, the test article is unloaded. After unloading, the separator gages are then applied at points where maximum shearing strains were measured in the coating during the initial loading. The test article is then loaded once again to the maximum load and strains are measured using the separator gages. Thus, two sets of data taken from two elastic deformations are combined to separate the principal strains. For the aft skirt test article it is known that in the weld and heat affected zone in the vicinity of the weld the material deforms inelastically with the proportional limit occurring at relatively low stress levels. Therefore, since unloading the inelastic test article and then reloading it for a second time causes completely different material behavior, it was not possible to follow the normal sequence of installing, and then taking data from, separator gages. Therefore, separator gages were bonded to the photoelastic coating prior to initial loading of the test

article and data were taken simultaneously for each load step.

Since separator gages occupy an area of 0.06 square inches and have a gage length for each perpendicular element of 0.063 inches, a penalty is paid in that optical readings using the polariscope cannot be made through the gage area and strain data are taken across lengths of 0.063 inches by the two separate perpendicular strain gage elements that are not located at the same point on the surface of the coating.

Considering the factors above in view of the relatively large strain gradients that exist in the weld material, across the fusion boundaries, and in the heat affected zone, values of shearing and principal strains obtained at separator gage locations are more representative of average strains in the area under the gage rather than strains at a point. These considerations for non-standard use of separator gages on the test article were discussed with NASA personnel during briefings in March and April, 1993.

V. CORRECTIONS TO MEASURED STRAINS

The basic equation (11) for maximum shearing strain is

$$\gamma_{max} = \epsilon_1 - \epsilon_2 = Nf \quad (1)$$

where N is the fringe order and

$$f = \frac{\lambda}{2t_p k}$$

where f = the fringe value,

λ = wavelength of light used = 22.7×10^{-6} in,

t_p = thickness of coating, and

k = calibration constant for the photoelastic coating.

The basic equation for the separator gage (11) is

$$\epsilon_1 + \epsilon_2 = \text{sum of principal strains} = \text{Sum} \epsilon \quad (2)$$

Thus, using equations (1) and (2), the principal strains may be separated.

However, both the difference of principal strains and the sum of principal strains are measured on the composite body at locations other than the surface of the test article where values are desired. The sum of the strains is measured on the surface of the coating and the difference in strains is measured at the midpoint of the thickness of the coating. Therefore, corrections to both of the measured values are required.

The test article was loaded fundamentally by axial forces and bending moments. Correction factors for bending of the composite body, C_b and K_b , are required if bending is present. However, correction factors for axial loading of the composite body are insignificant when compared to correction factors for bending because of the thickness of the coating relative to the thickness of the metal in the weld area. Therefore, no axial correction factors were used. For corrections to the difference in principal strains, the equation

$$C_b = \frac{1 + E^* (4t^* + 6t^{*2} + 4t^{*3}) + E^{*2}t^{*4}}{1 + t^*}$$

must be applied (11).

For corrections to the sum of principal strains, the equation

$$K_b = \frac{1 + E^* (4t^* + 6t^{*2} + 4t^{*3}) + E^{*2}t^{*4}}{1 + 2t^* + E^*t^{*2}}$$

must be applied (11). In these equations,

$$E^* = E_{\text{plastic}}/E_{\text{metal}}$$

where

$$E_{\text{plastic}} = 420,000\text{psi}$$

and

$$t^* = t_{\text{plastic}}/t_{\text{metal}} = 0.0472$$

For the aft skirt test article, the plastic thickness was 0.0679 inches and the thickness of the metal was 1.4375 inches measured at the weld. The thickness of the metal on either side of the weld was essentially the same. For separation of principal strains at a point, the equations (11)

$$\epsilon_1 = \frac{(\text{Sum}\epsilon)K_b + \gamma_{\text{max}}(C_b)}{2}$$

and

$$\epsilon_2 = \frac{(\text{Sum}\epsilon)K_b - \gamma_{\text{max}}(C_b)}{2}$$

were used.

Since material in the weld and for a distance to either side of the weld in the heat affected zone behaves inelastically (1,2,12), the stiffness (tangent modulus) decreased as a function of the applied stress. Previous work (2) has shown values of the tangent modulus for 2319 pure weld material and for 2219-T87 pure plate material. No previous data for the tangent modulus are available for the forged material. Therefore, in this test, it was assumed that values of the tangent modulus for stresses above the proportional limit for plate and forged metal are the same.

Tangent modulus curves for weld and plate material in the welded joint were constructed from those given in (2) by using proportional limits in the welded joint determined by plotting stress-strain curves at the weld centerline and at a location 0.50 inches away from the weld centerline. These points were, of course, in the heat affected zone of the welded joint.

Using tangent modulus curves for the welded joint on a piecewise continuous basis, values for C_b and K_b were calculated and are given in Tables 1 and 2 for selected ranges of maximum shearing strain in the weld metal and plate metal respectively. These curves and tables are contained in the Appendix.

VI. RESULTS

Figures 9 through 23 show values of strain as a function of percent of applied load. The first twelve figures, numbers 9 through 20, give strains at points where principal strains were separated. Some non-linearity exists above the 20% load at points 1, 16, 17, 18, 20, and 21 whereas general linearity exists at points 2, 4, 8, 9, 10, and 11. The largest strains among these points at the various loads exist at points 8, 9, 10, and 11 which are located 0.50 inches

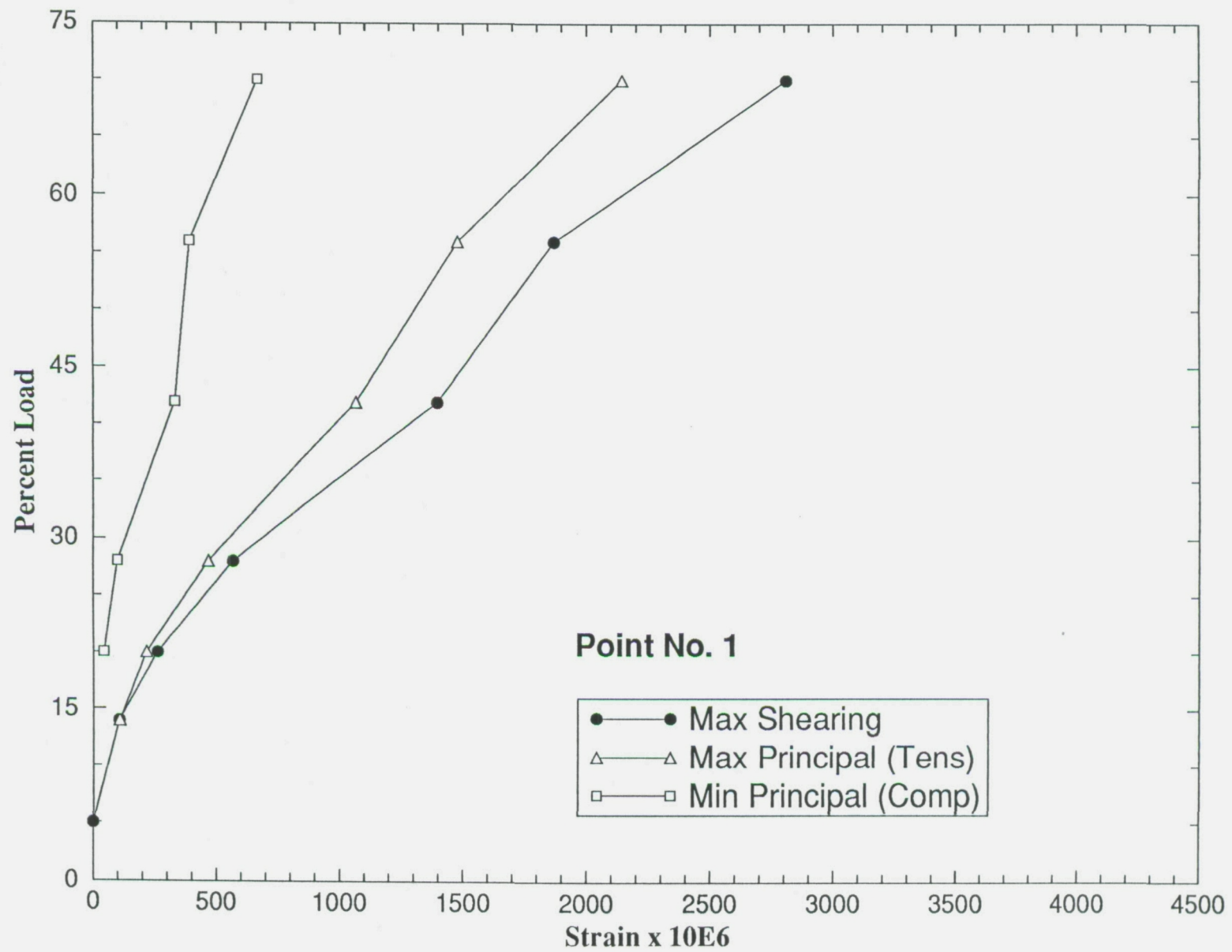


Figure 9. Strains at Point 1

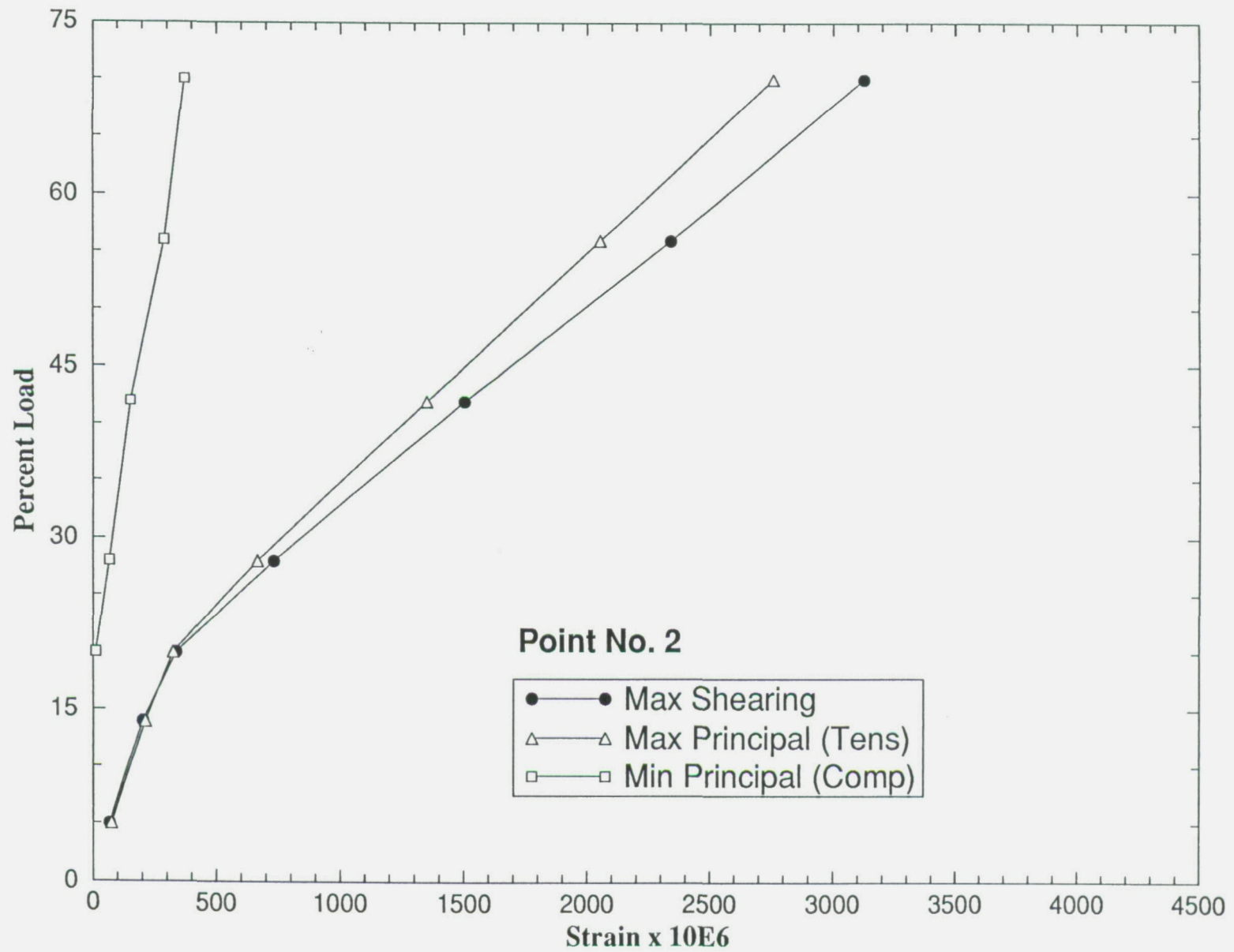


Figure 10. Strains at Point 2

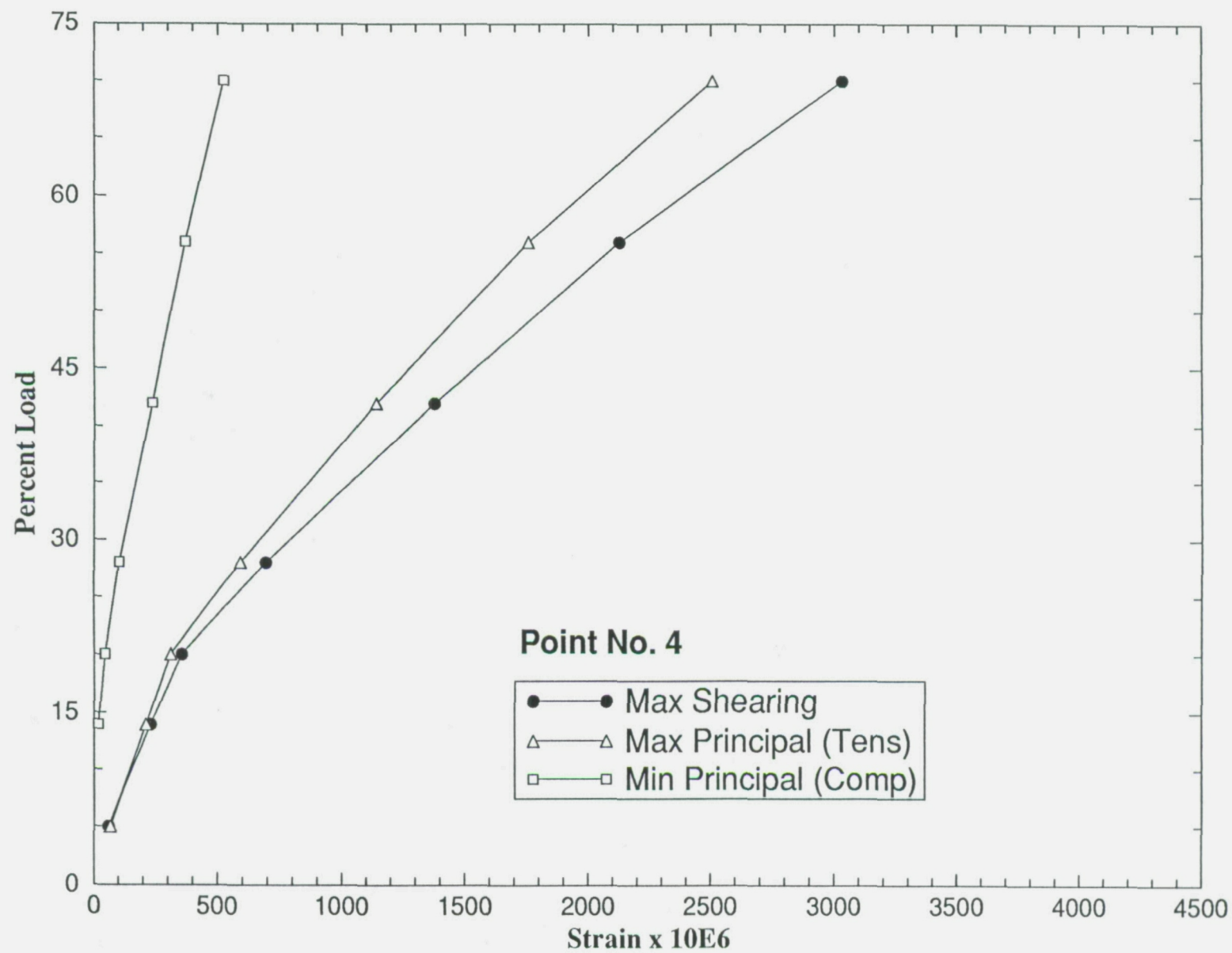


Figure 11. Strains at Point 4

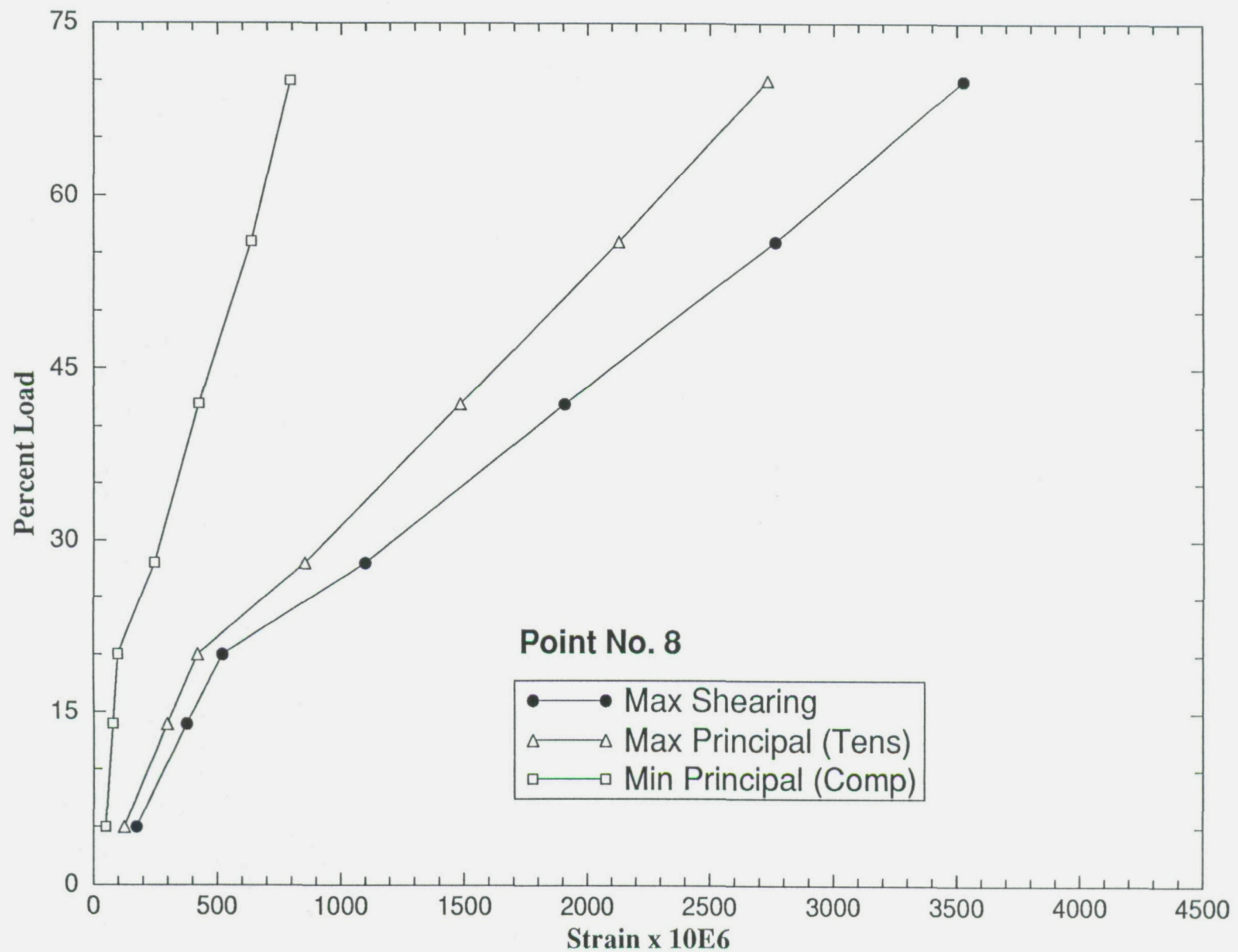


Figure 12. Strains at Point 8

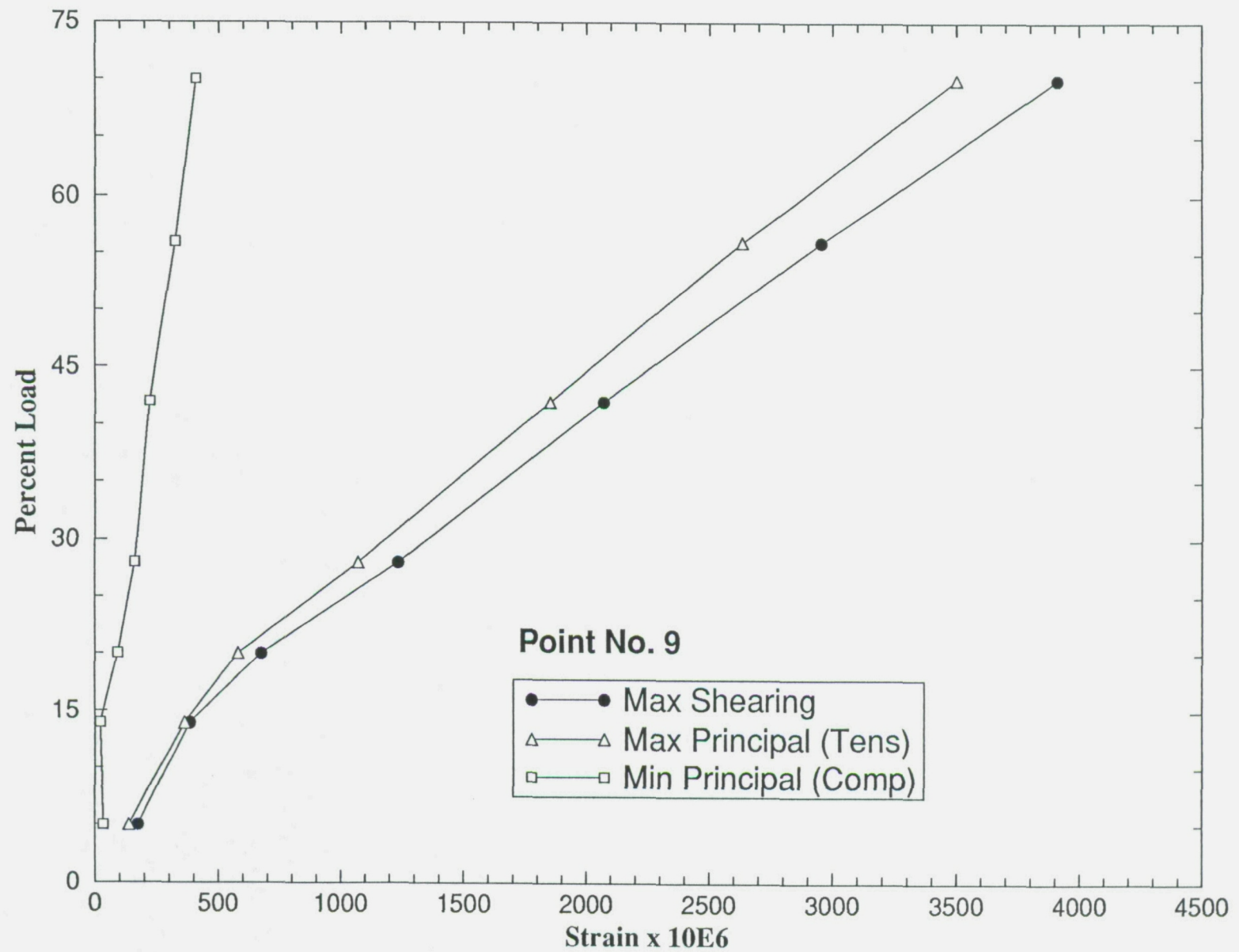


Figure 13. Strains at Point 9

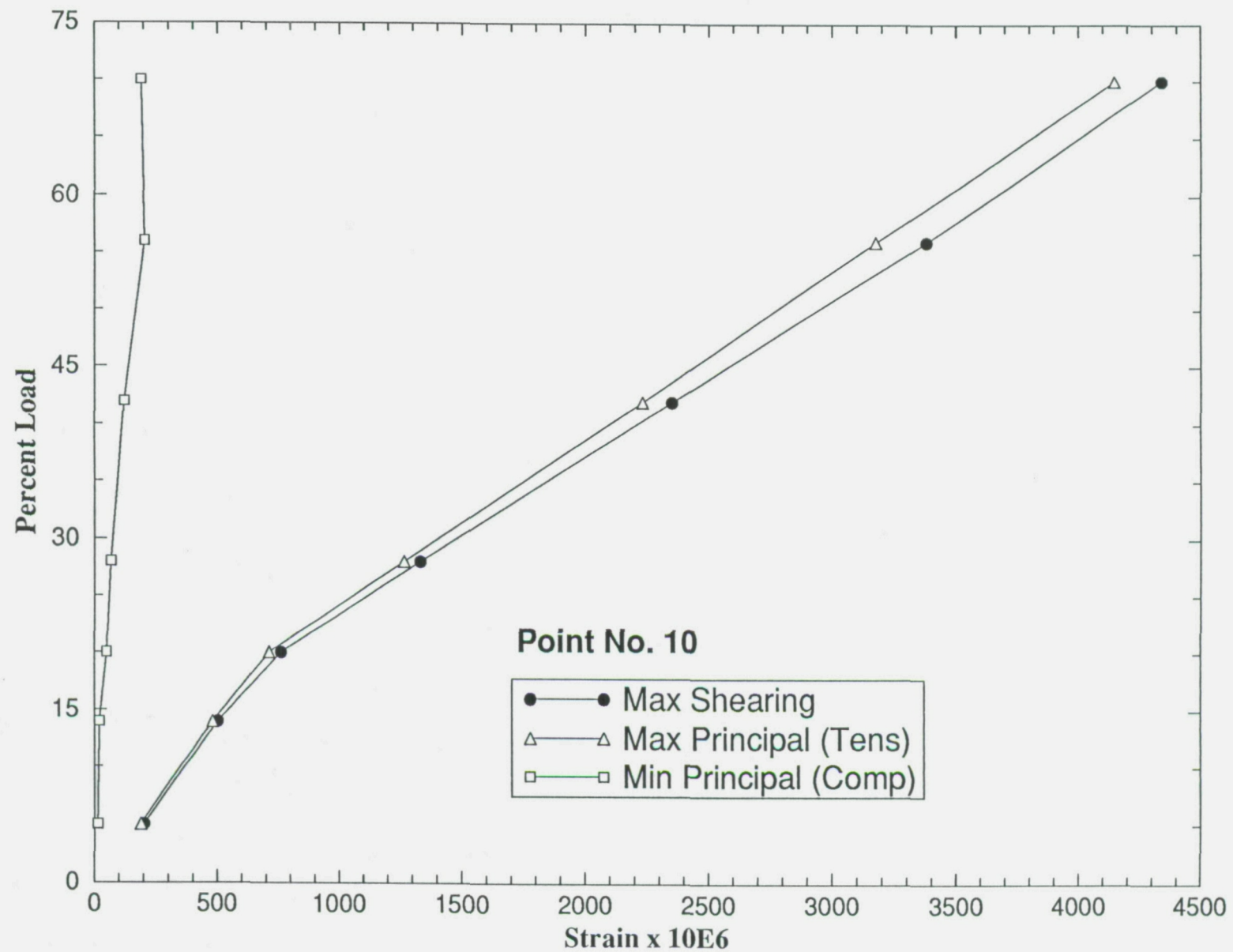


Figure 14. Strains at Point 10

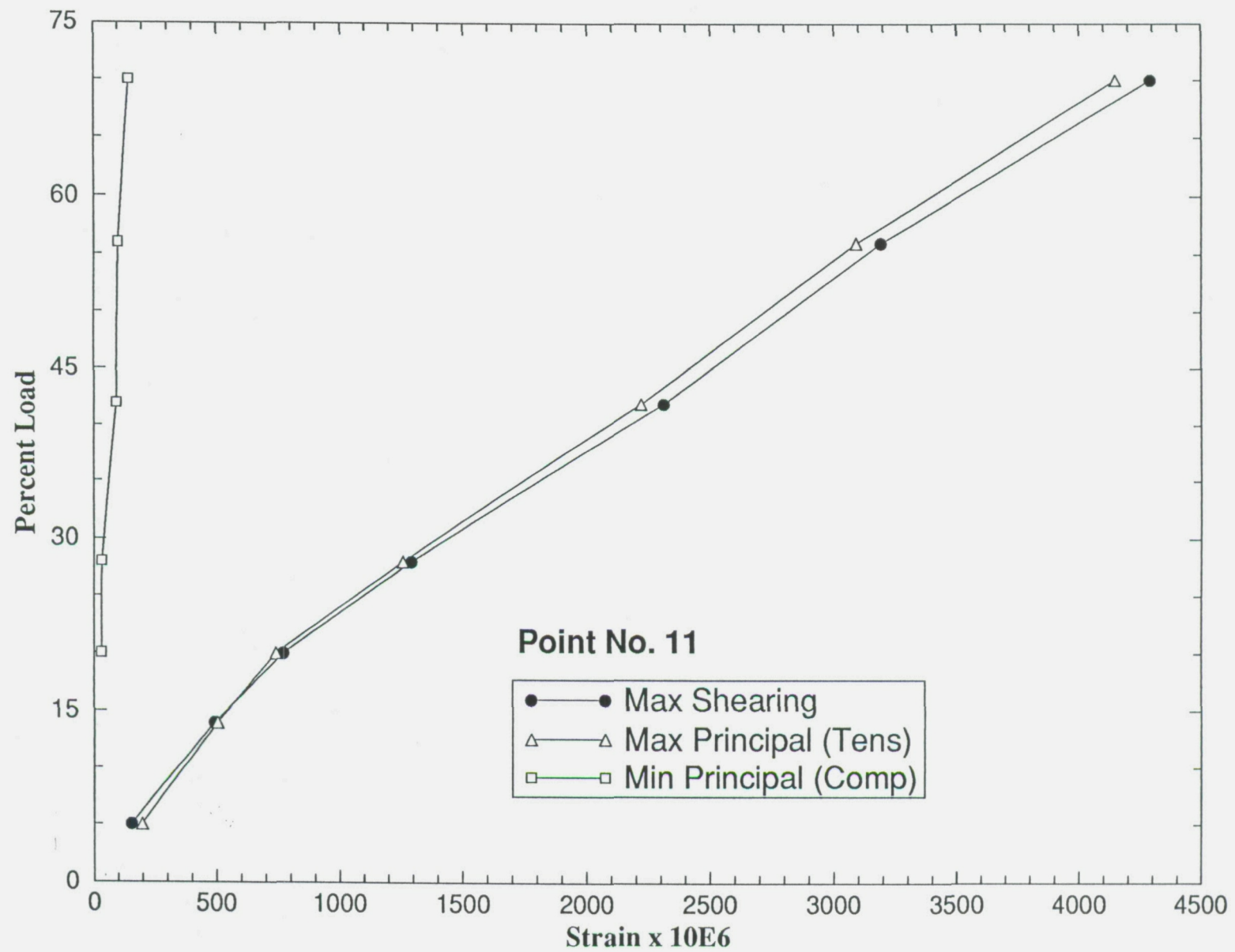


Figure 15. Strains at Point 11

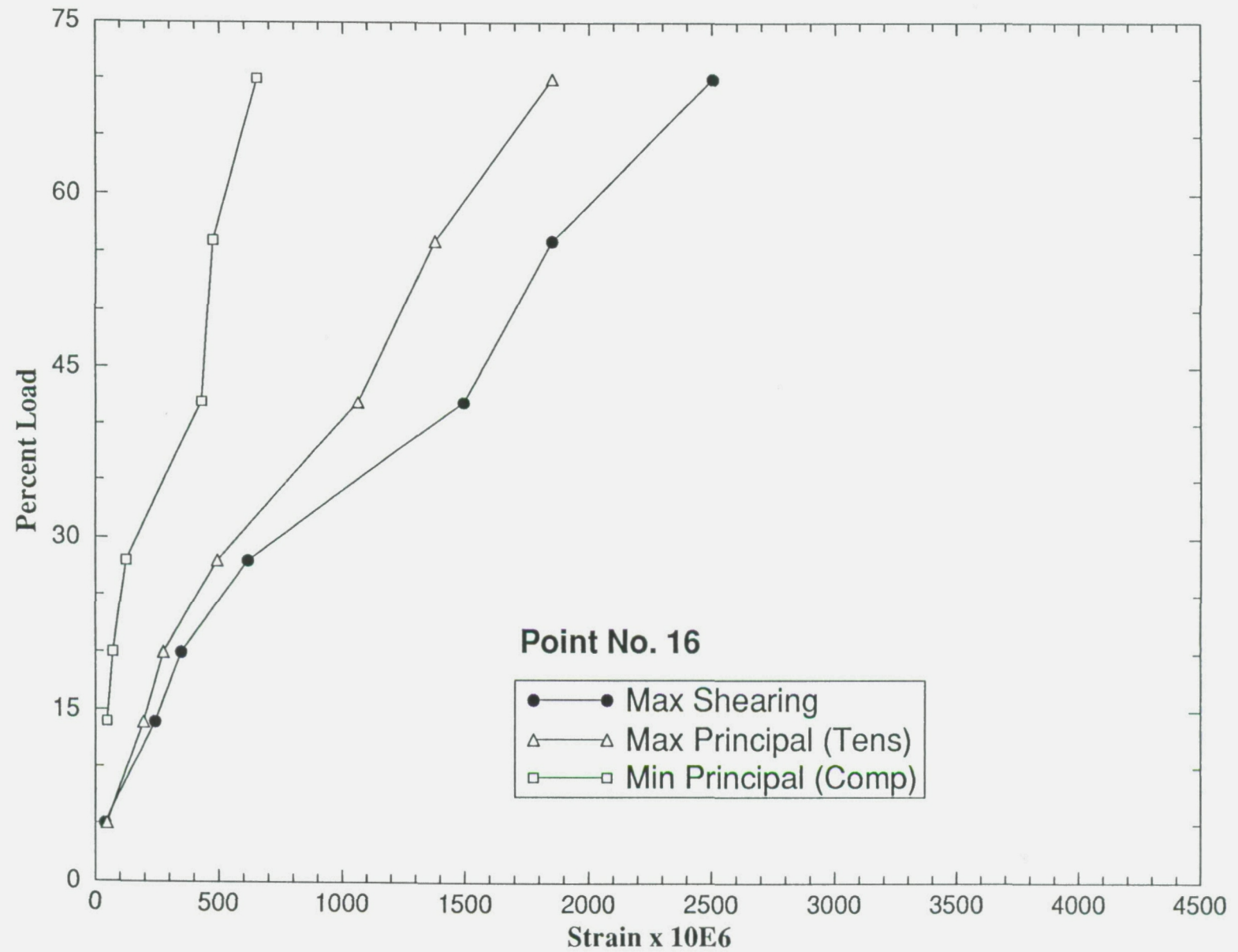


Figure 16. Strains at Point 16

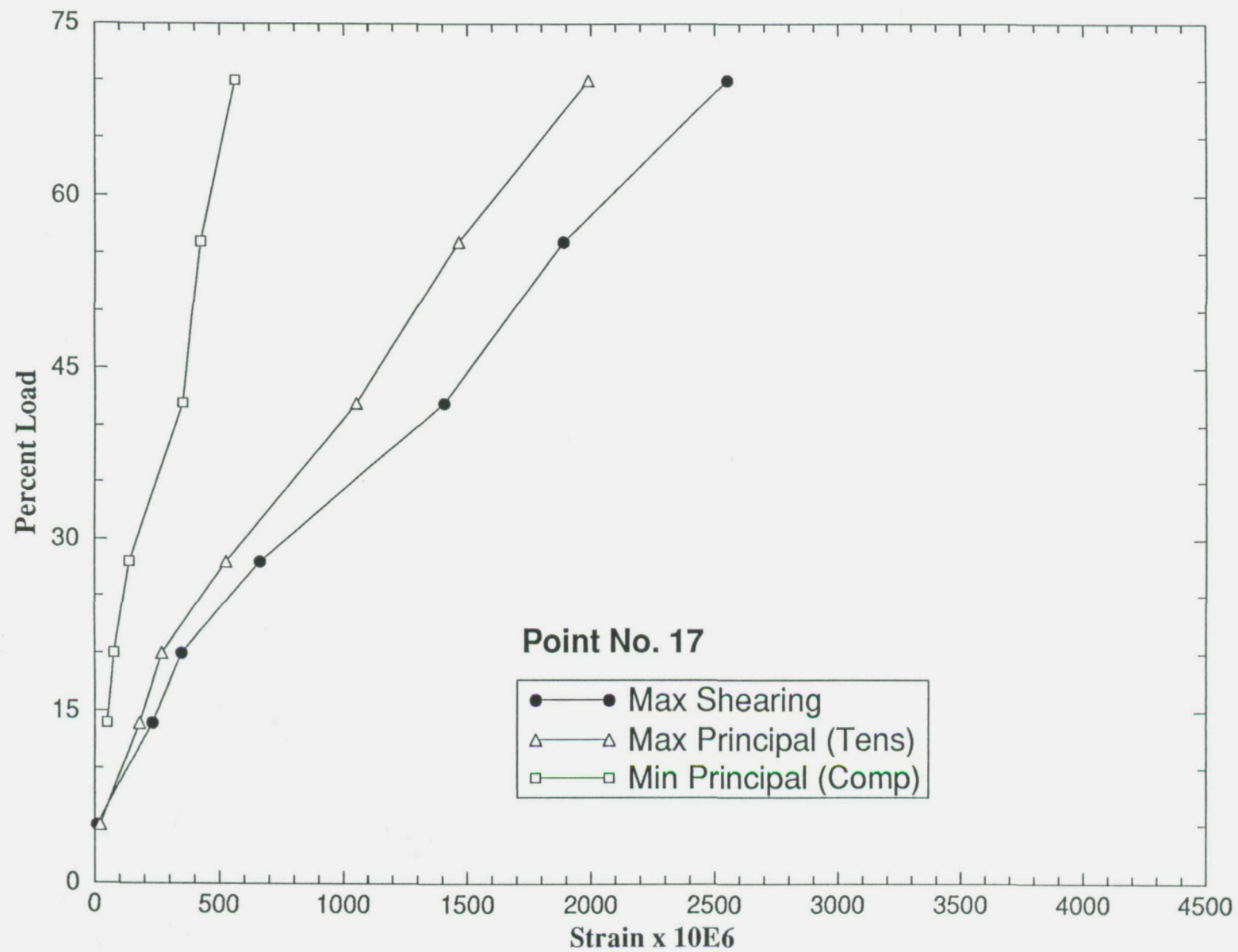


Figure 17. Strains at Point 17

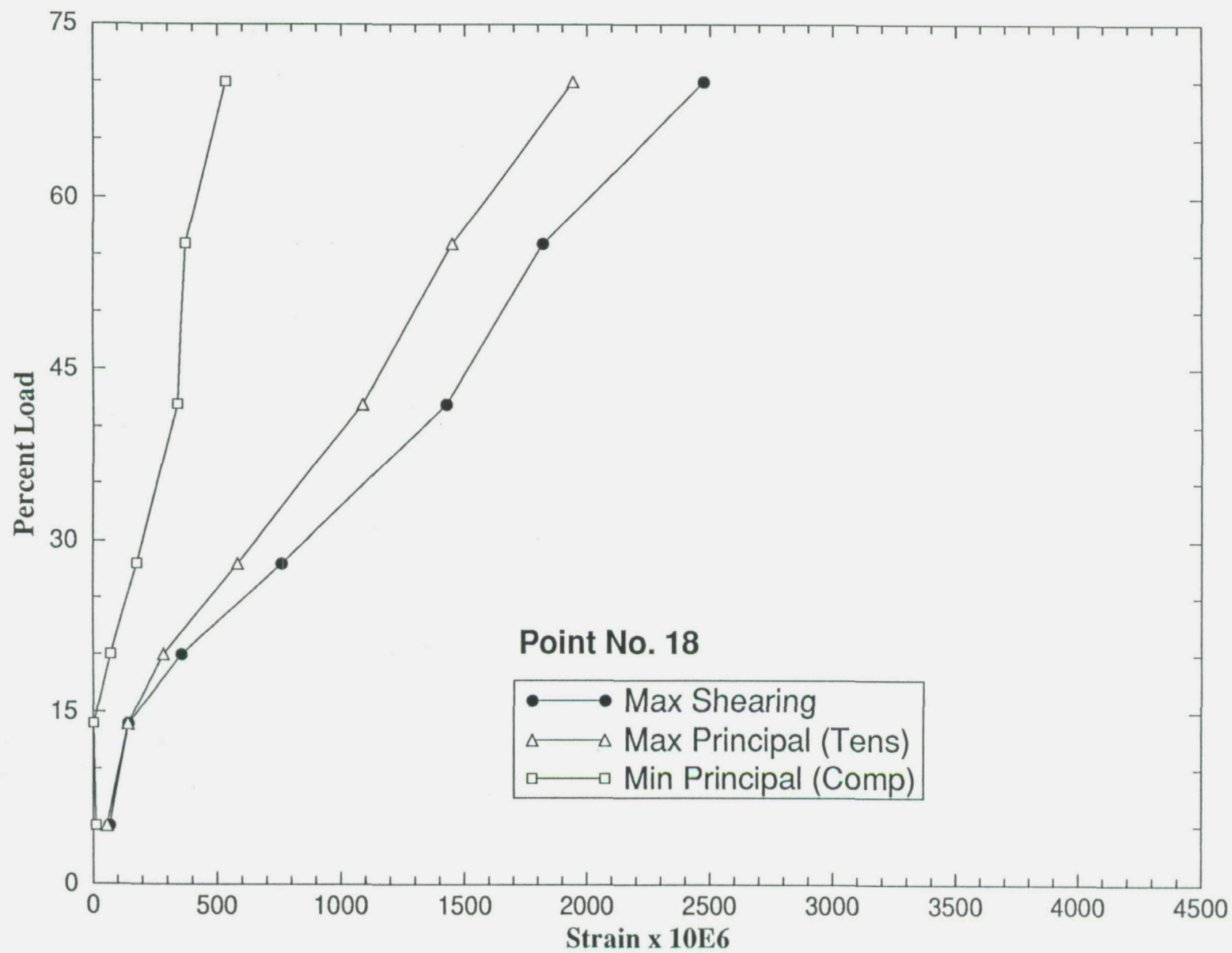


Figure 18. Strains at Point 18

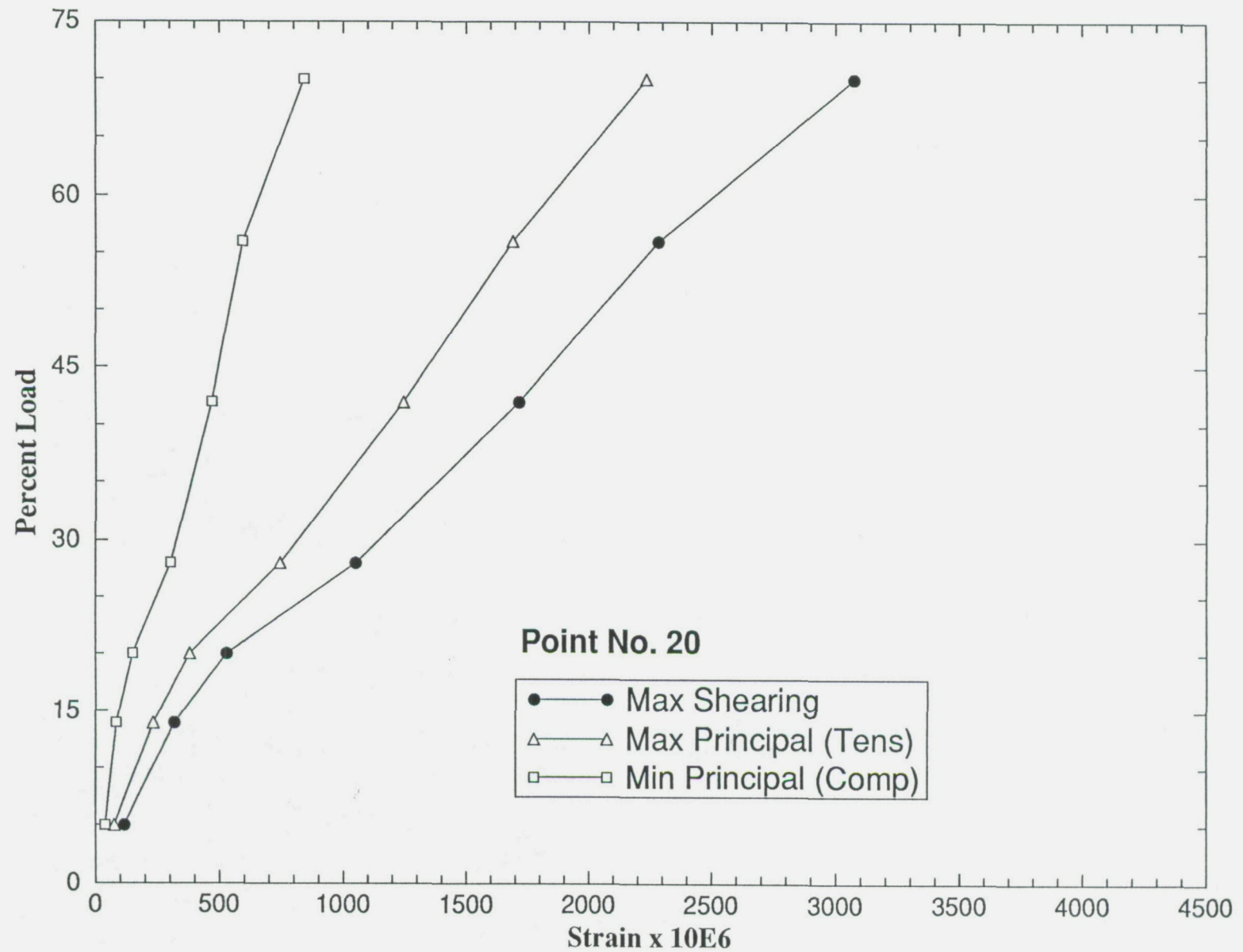


Figure 19. Strains at Point 20

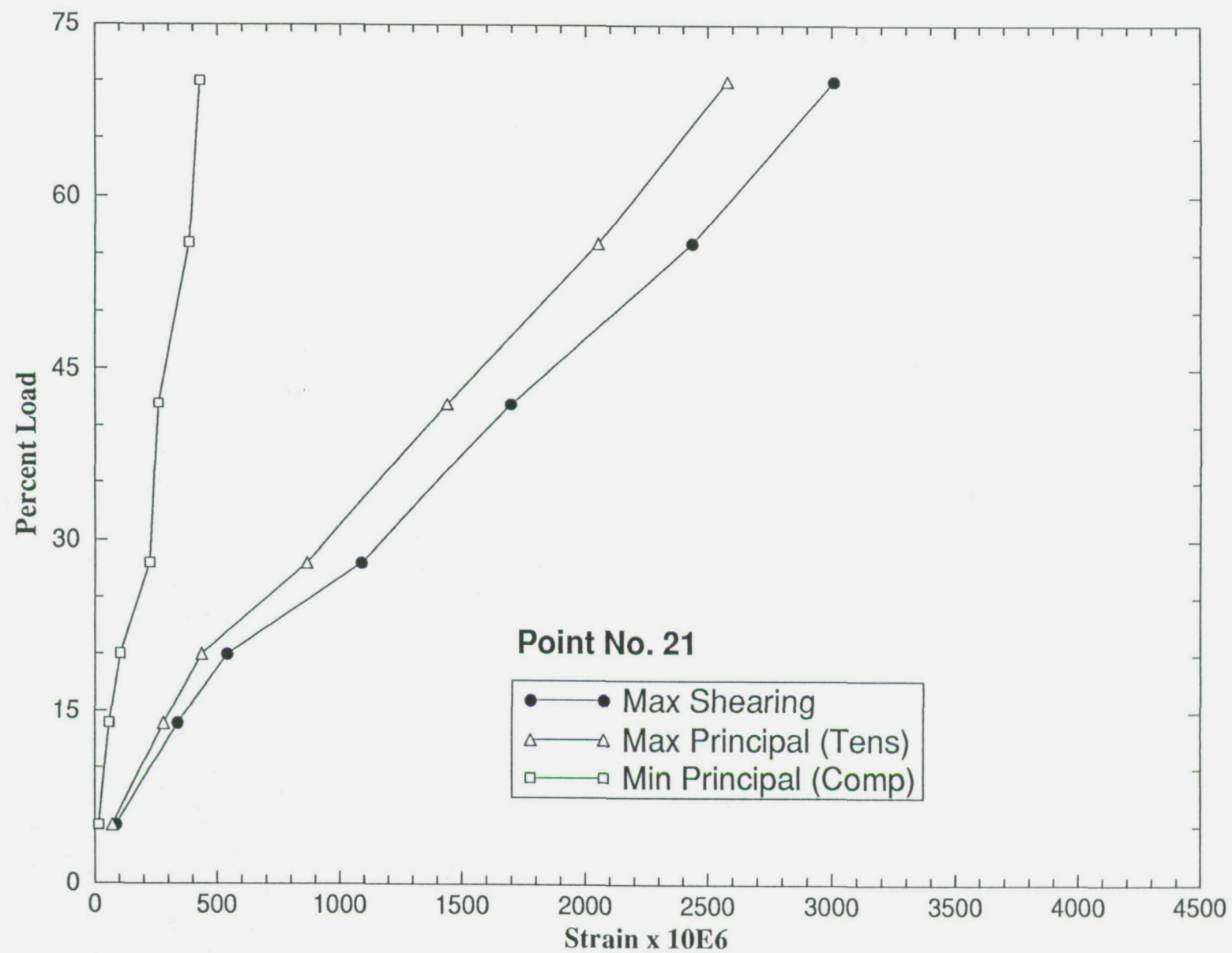


Figure 20. Strains at Point 21

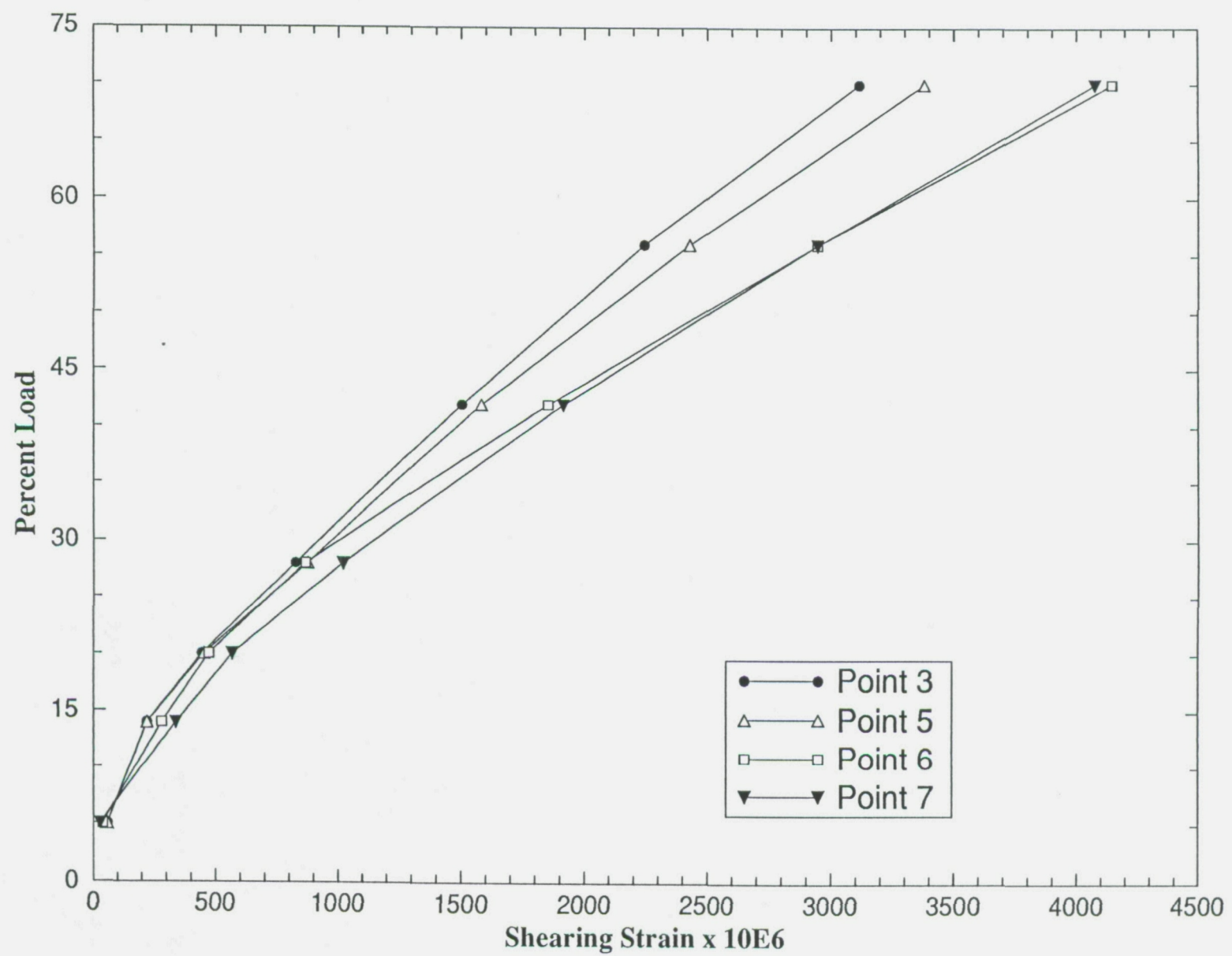


Figure 21. Shearing Strains at Points 3, 5, 6, 7

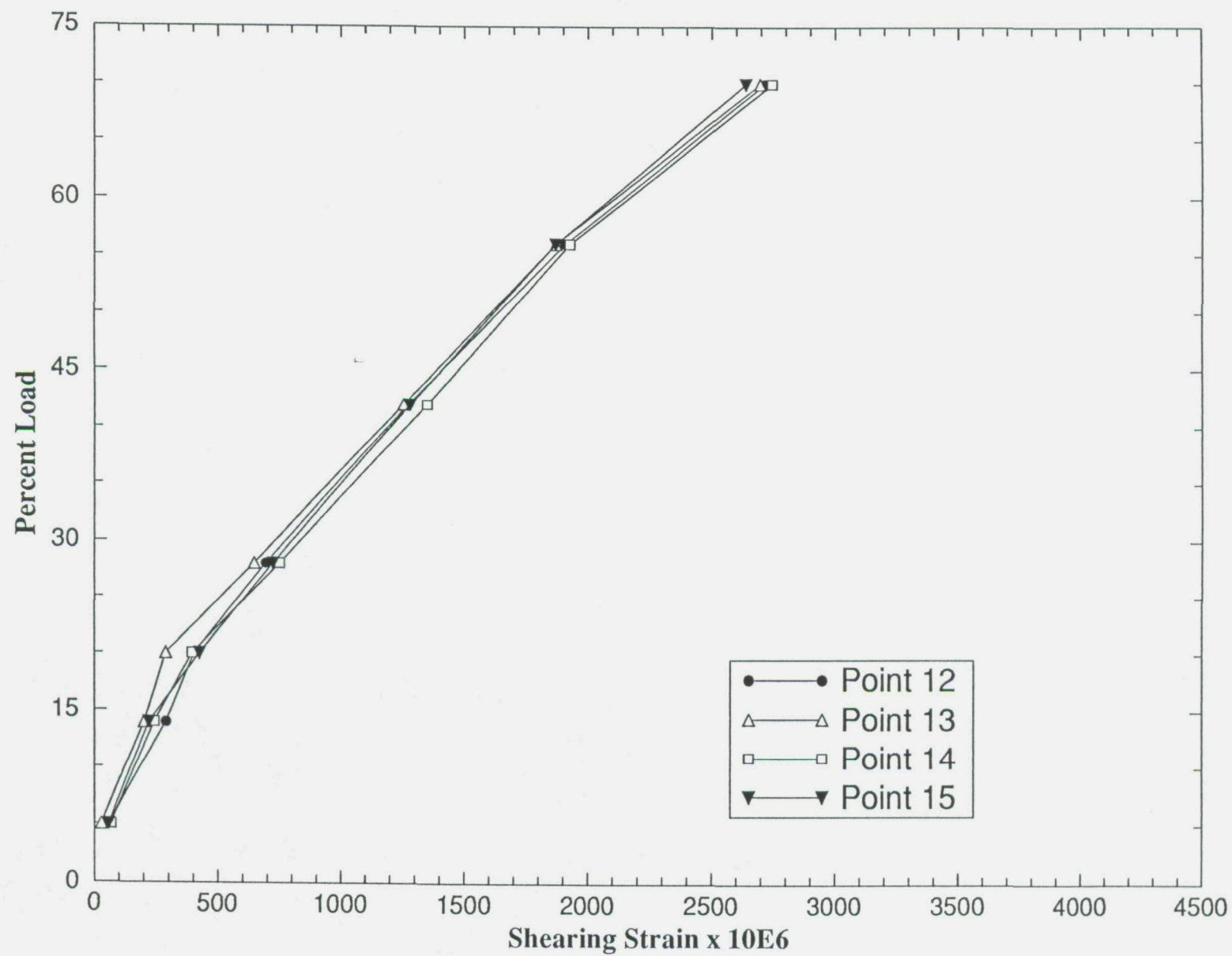


Figure 22. Shearing Strains at Points 12, 13, 14, 15

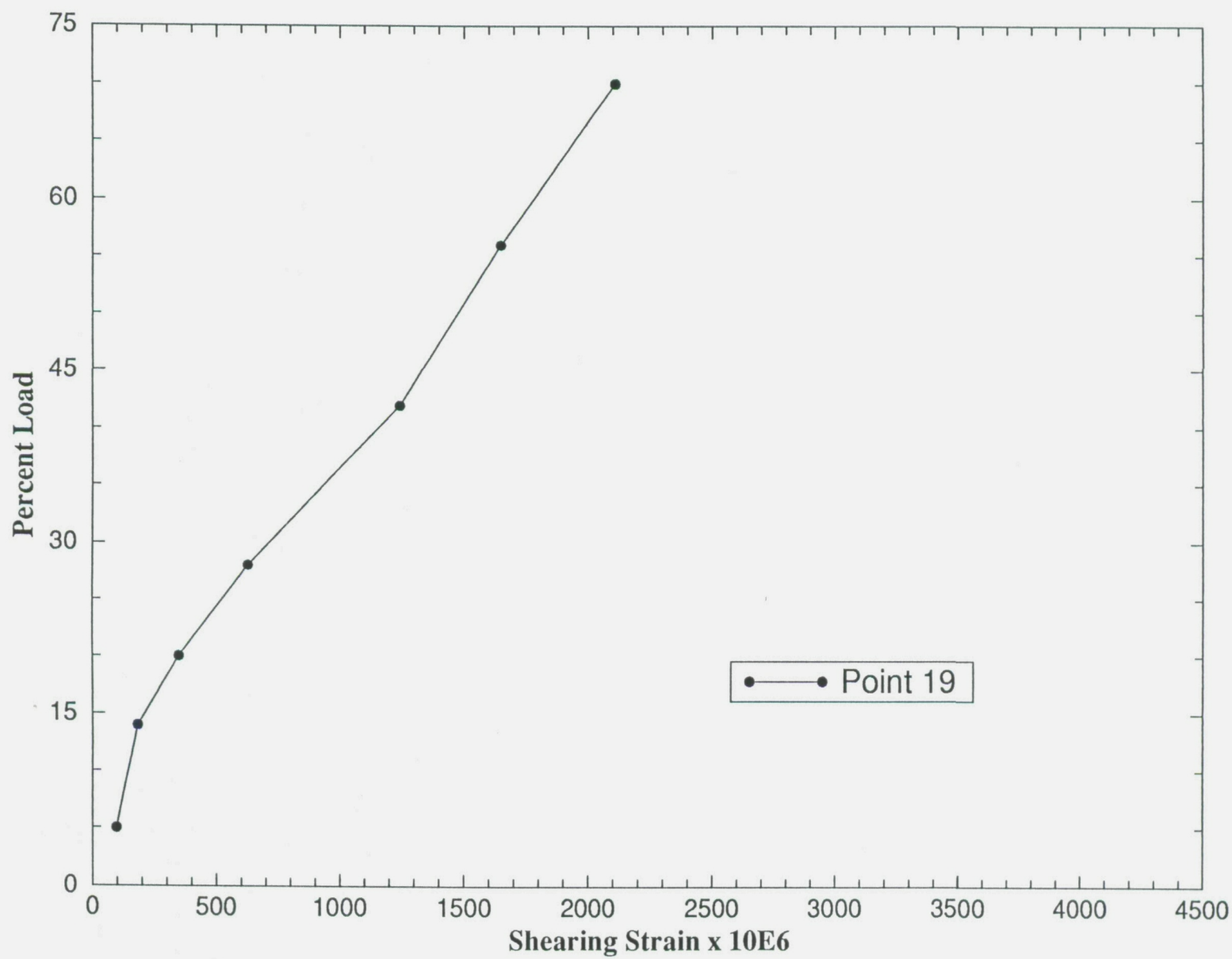


Figure 23. Shearing Strains at Point 19

from the weld centerline into the forged metal.

Figure 21 gives maximum shearing strains at points 3, 5, 6, and 7 and reflects general linearity above the 20% load with the strain magnitude increasing as locations are observed from point 3 to point 7. These points are located in the weld material along a line 0.1875 inches from the weld centerline toward the forged metal.

Figure 22 shows maximum shearing strains at points 12, 13, 14, and 15 and reflects a slight non-linearity above the 20% load. For practical purposes, all these points have equal values of strain and are located in the plate metal 0.56 inches from the weld centerline.

Photographs 11 through 17 show fringe patterns at the various loads. Except for Photograph 11, two views of the photoelastic coating are given. The top view (or face) is taken in a direction normal to the weld and the bottom view (or fillet) is taken in a direction normal to the throat of the fillet connecting the aft skirt to the holddown post. Fringe patterns observed normal to the weld (face view) apply at all points except points 20 and 21 and other locations in the throat of the fillet.

Noting the patterns at 42% load, one can clearly note development of larger strains at points 5, 6, 7, 8, 9, 10, and 11 and, to a lesser extent at points 20 and 21. These trends continue in photographs of the 56% and 70% loads.

Photograph number 17 shows residual strains at tare. It is clearly seen that points in the weld material and to either side of the fusion boundaries have permanent strain. Fusion boundaries are seen as the thin, dark lines (zero fringe order) on either side of and parallel to the weld centerline. Material in the fusion boundaries has not yielded. Yielding may be

ORIGINAL PAGE
COLOR PHOTOGRAPH

Face View

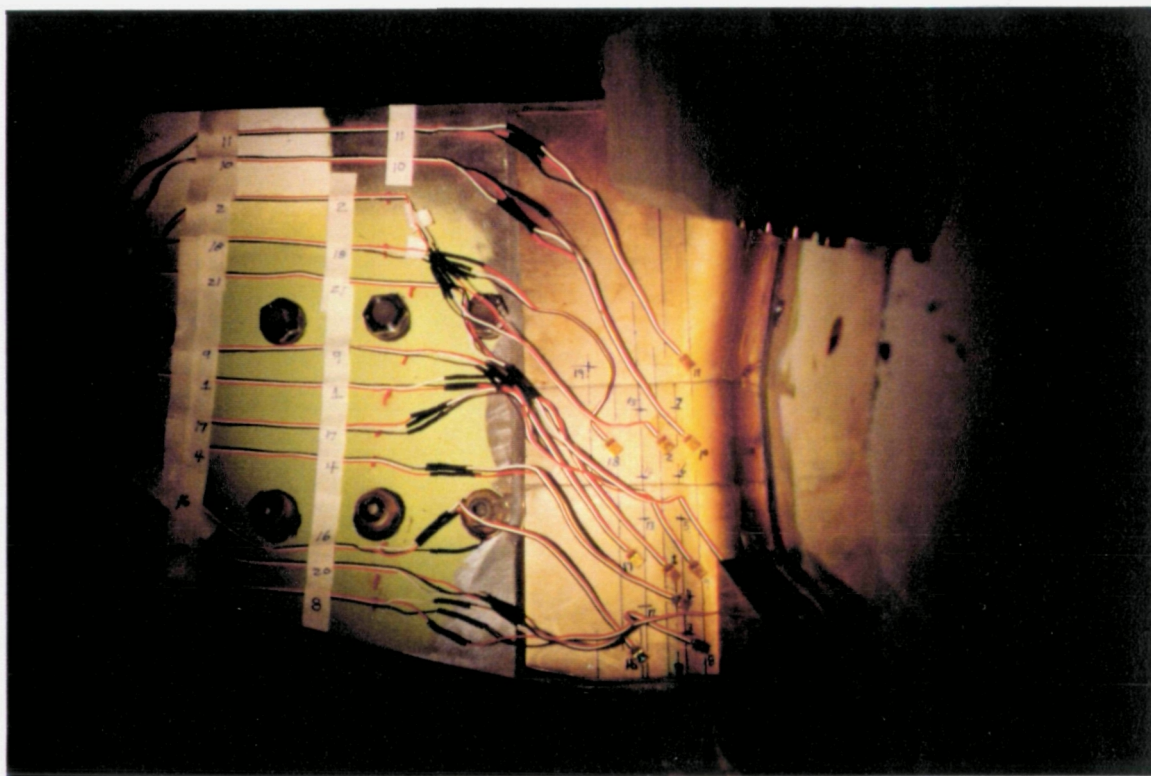
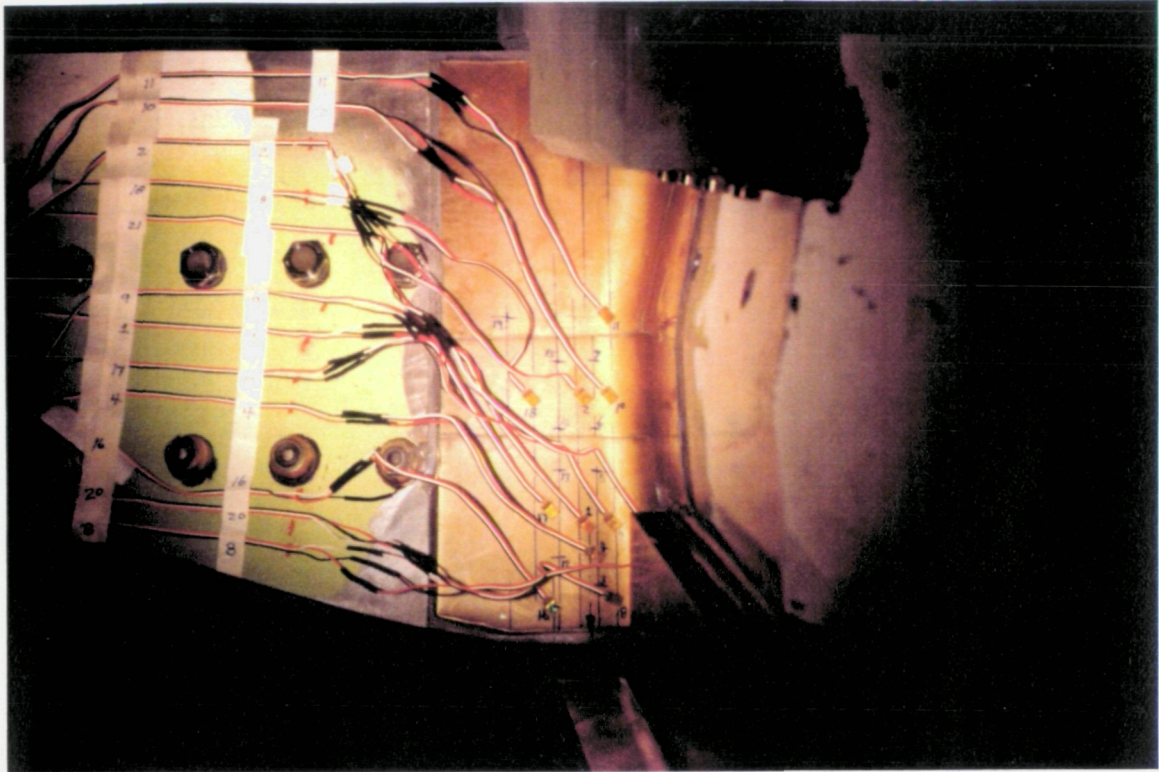


Photo 11. Fringe Pattern at 14% Load



Fillet View

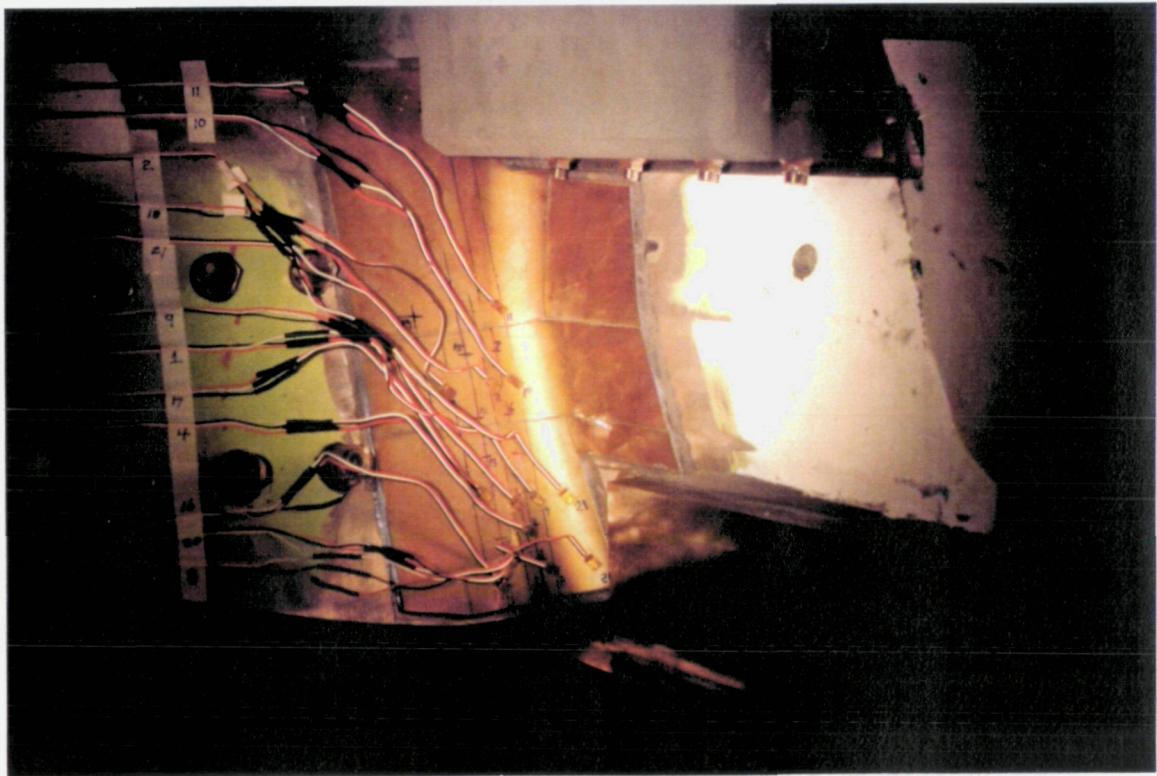


Photo 12. Fringe Patterns at 20% Load



Fillet View

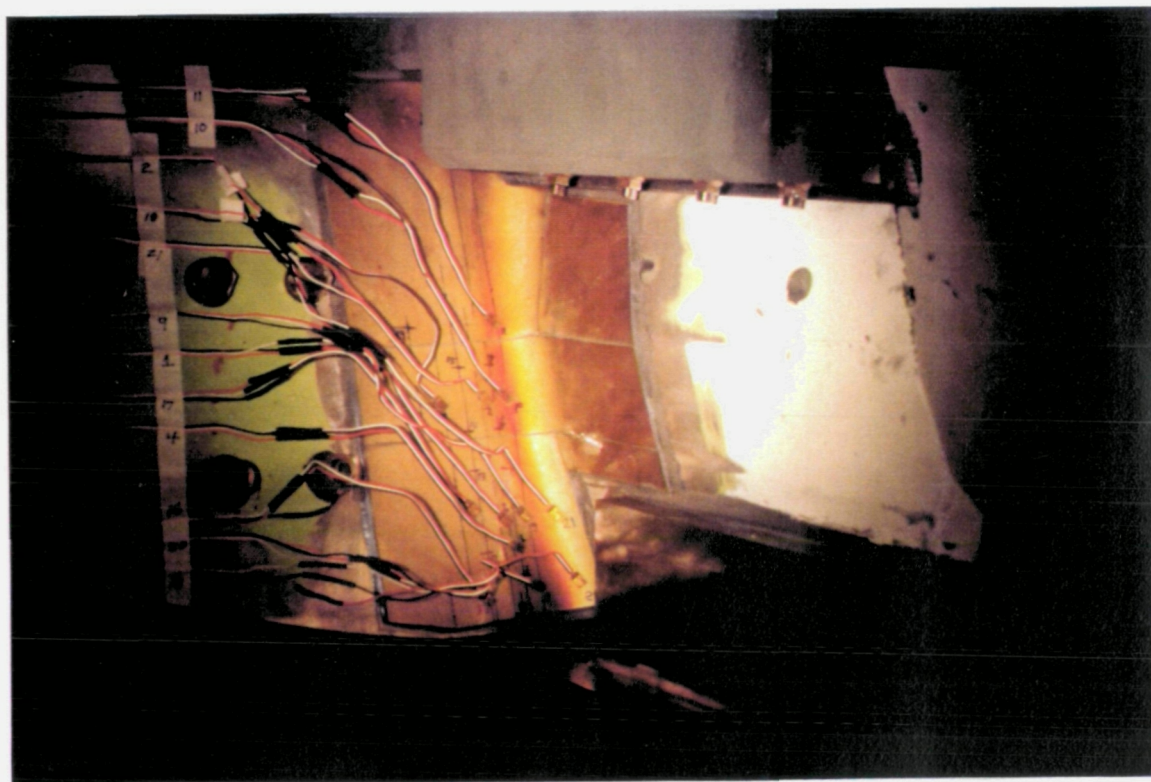
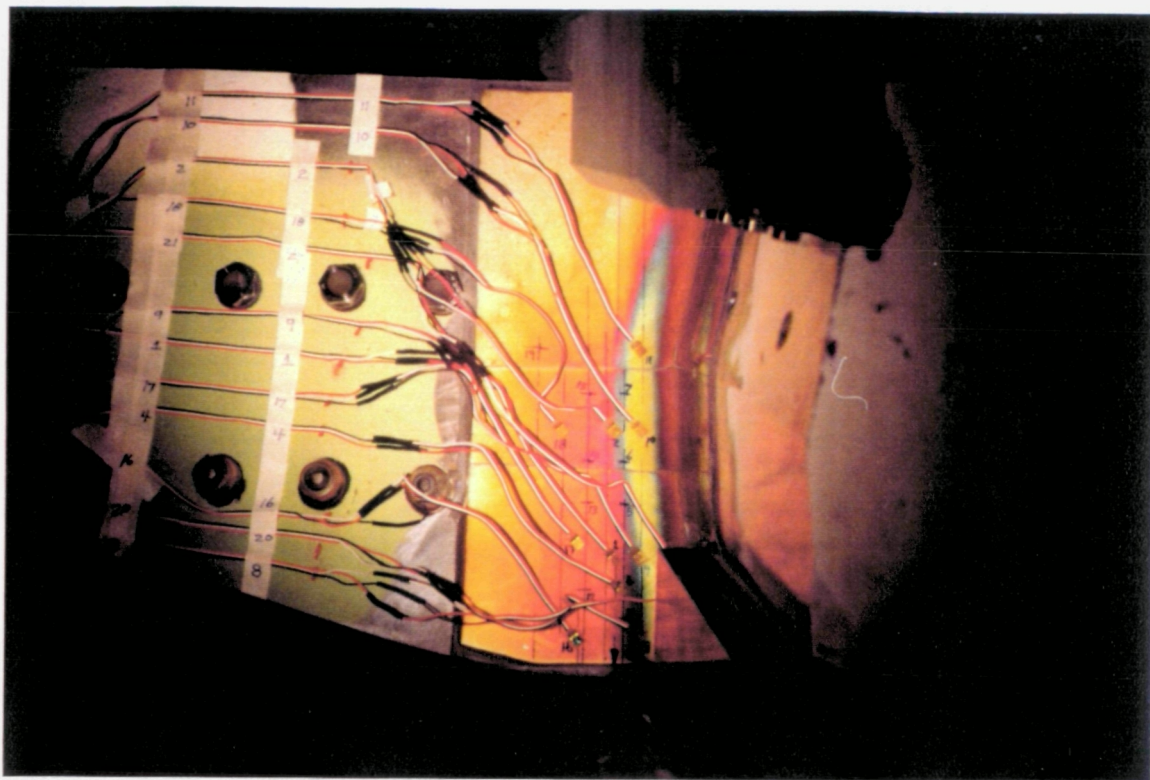


Photo 13. Fringe Patterns at 28% Load



Fillet View

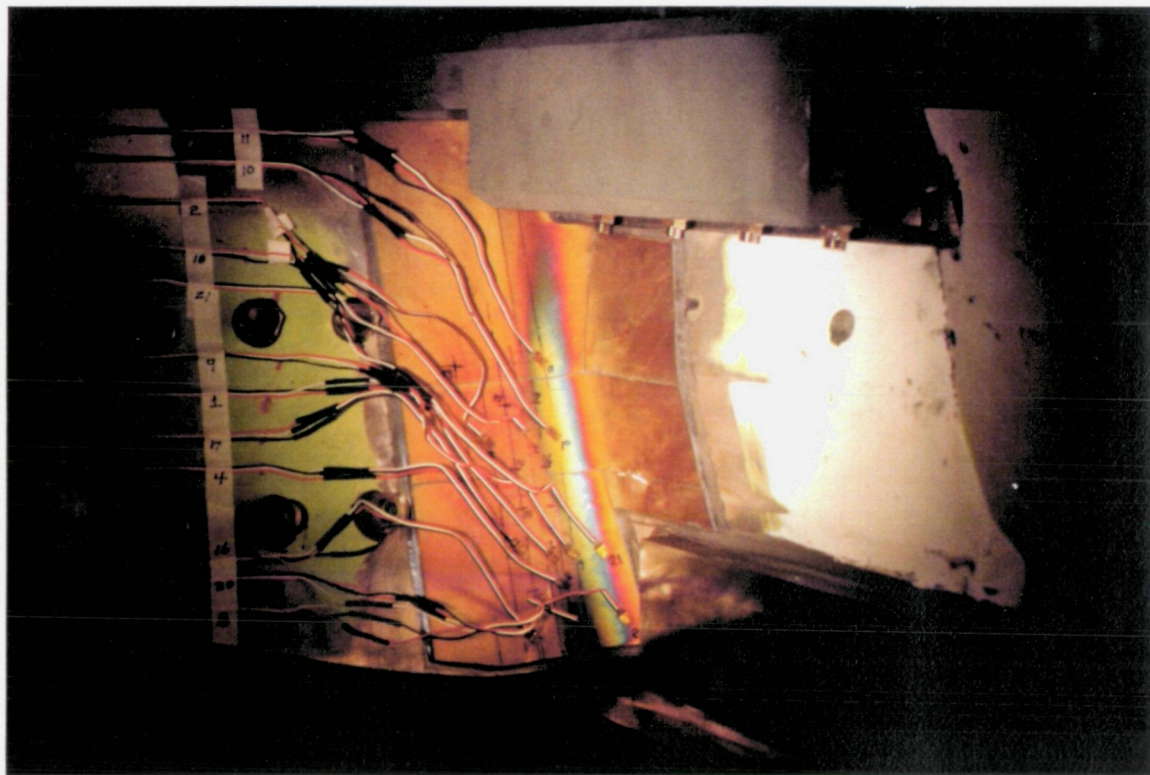


Photo 14. Fringe Patterns at 42% Load



Fillet View

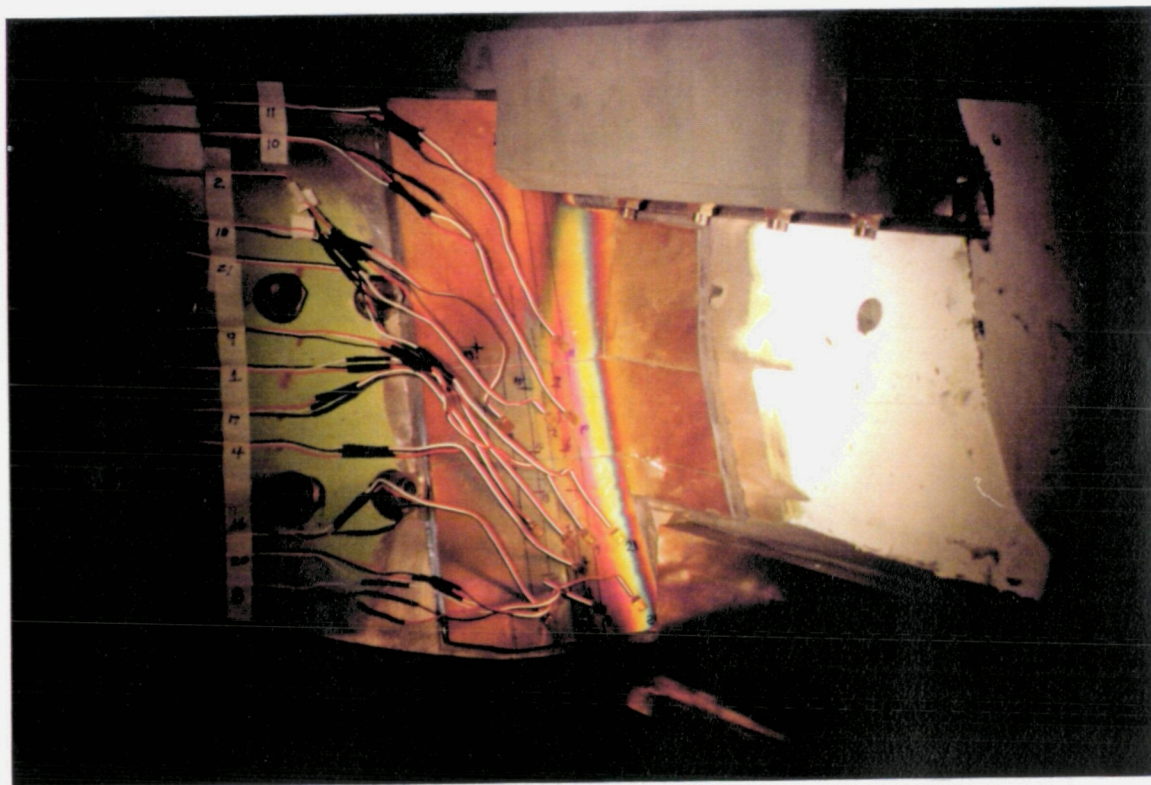
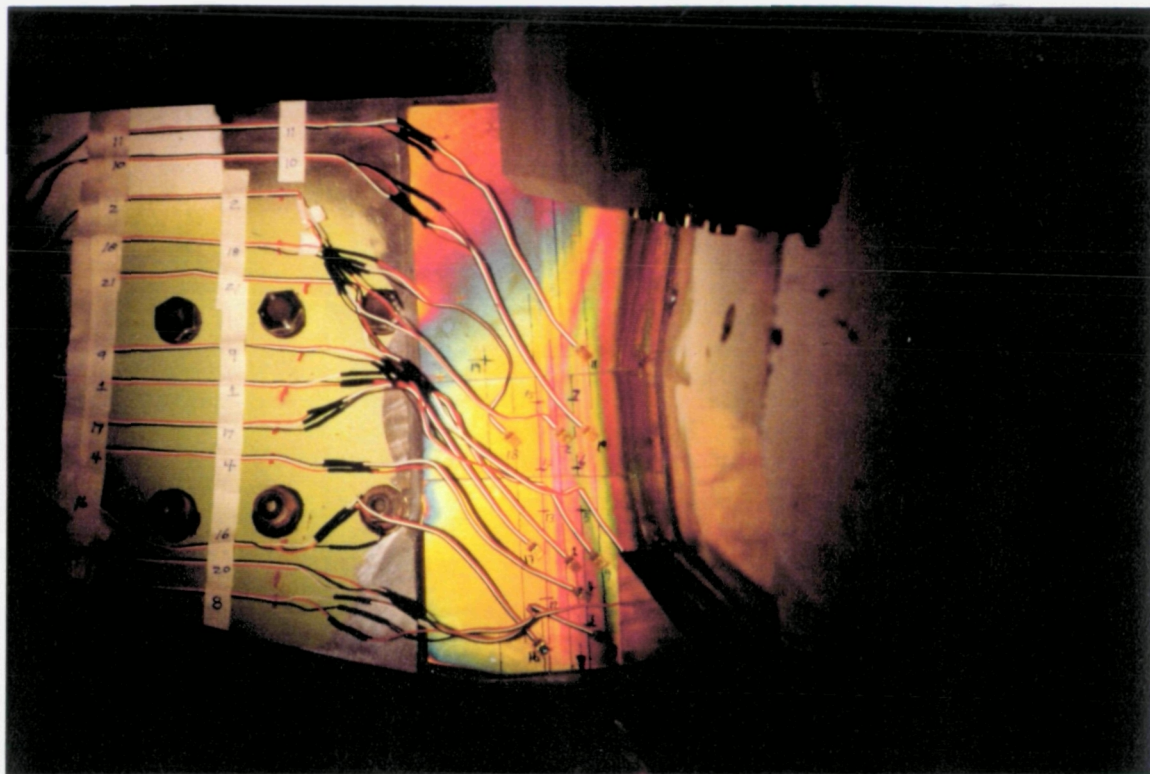


Photo 15. Fringe Patterns at 56% Load



Fillet View

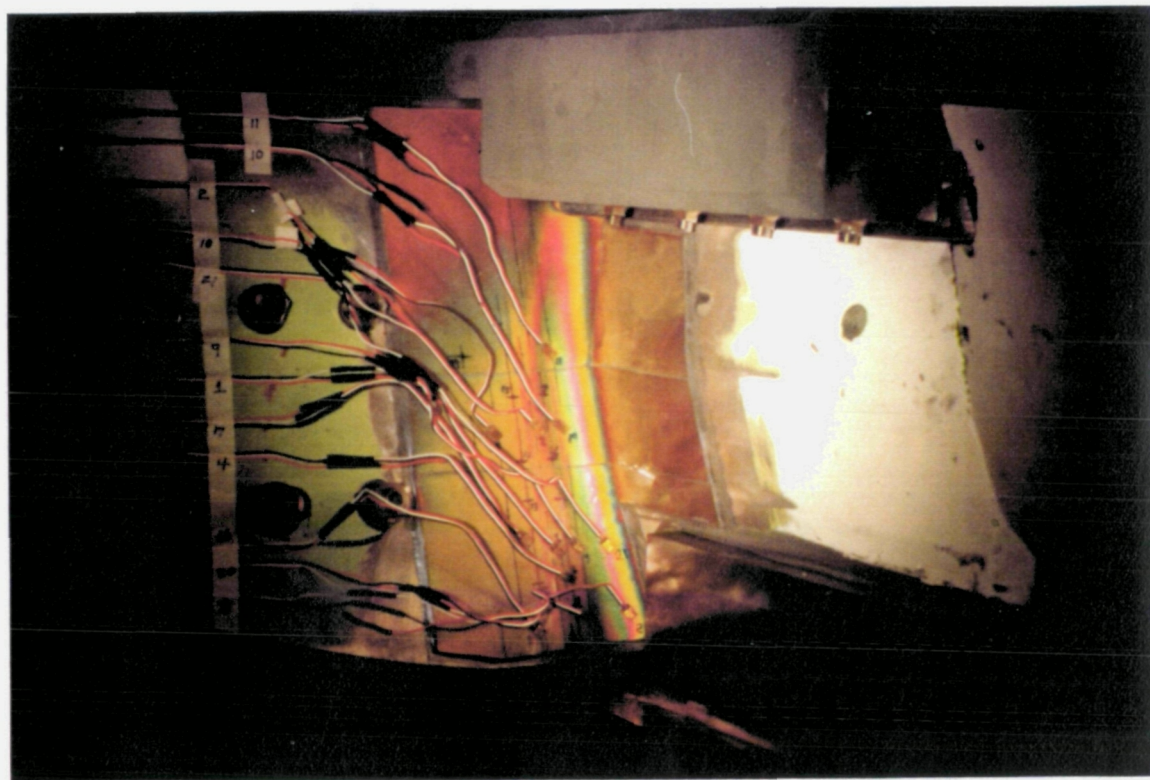
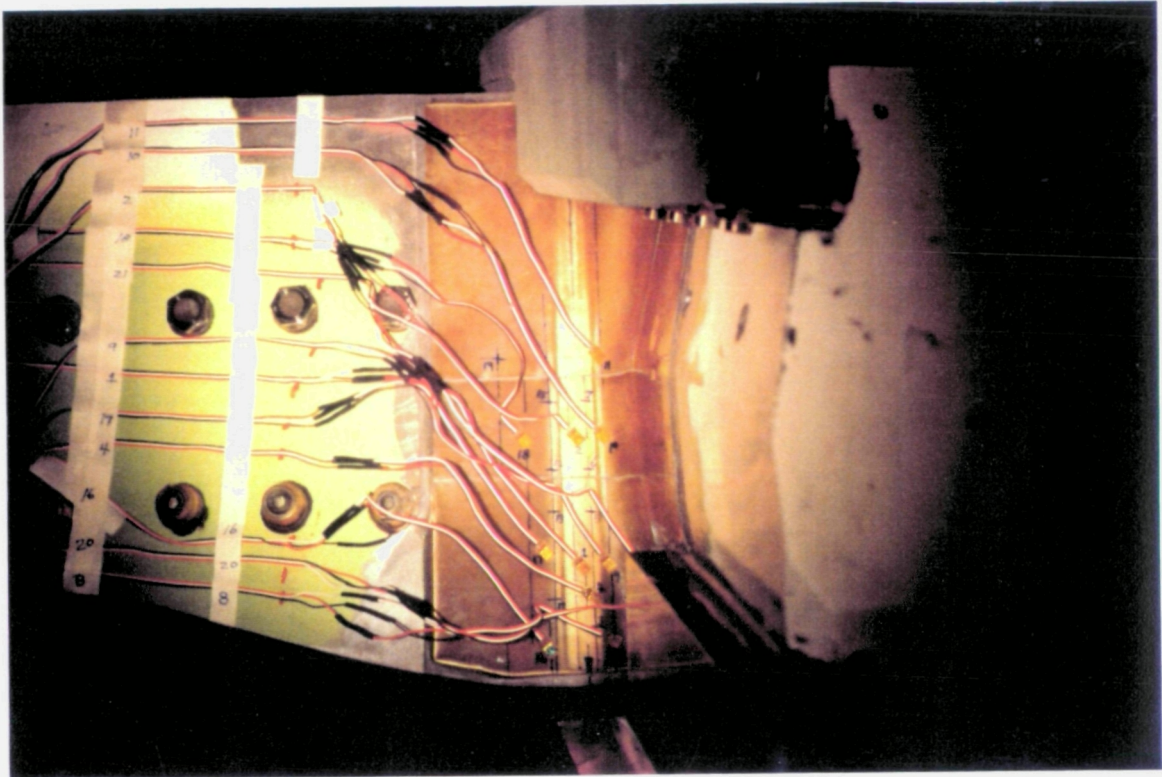


Photo 16. Fringe Patterns at 70% Load



Fillet View

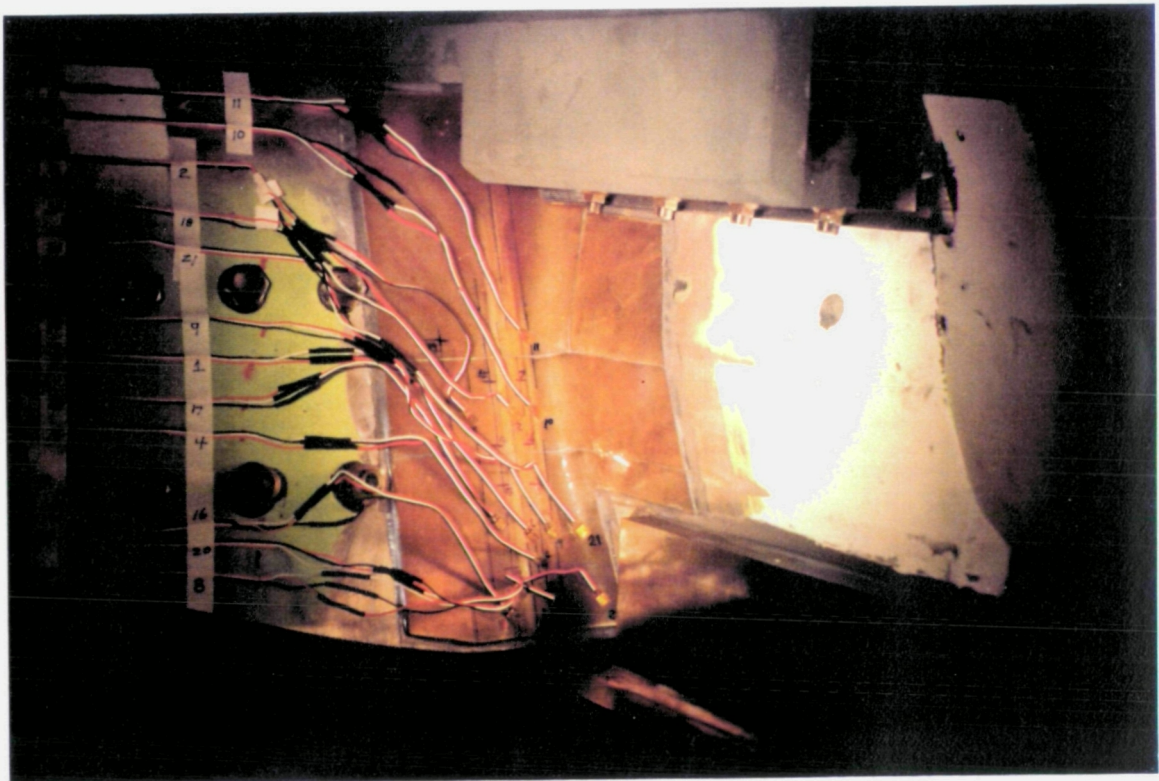


Photo 17. Fringe Patterns at Tare

observed at points 1, 2, 3, 4, 5, 6, 7, 10, 11, 12, 13, 14, and 15. No yielding was observed at points greater than 0.60 inches from the weld centerline.

Observation of the face view fringe pattern in Photograph 17 indicates that the greatest yielding occurred horizontally between the fusion boundaries and vertically from point 3 to just above point 11. Also, yielding can be observed for a small distance from the fusion boundaries into both the plate and forged metal.

VII. REFERENCES

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12. Gambrell, S. C., Jr., "Use of Photostress and Strain Gages to Analyze Behavior of Weldments," Final Report, Contract No. NAG-8-293, SUB93-101, University of Alabama in Huntsville/NASA, BER Report No. 591-97, Fall 1993.

VIII. APPENDIX

Figures 24 through 30 indicate various mechanical properties of material in the welded joint. Non-linearity of material behavior at the weld centerline and at the point one-half inch from the weld centerline can be clearly seen in Figures 24 and 25.

Measured contraction ratios for points at the weld centerline and at the point one-half inch from the weld centerline on the *OD* side are given in Figures 26 and 27.

Tangent modulus curves for the pure weld and plate material and tangent modulus curves for the welded joint at the weld centerline and for a point one-half inch from the weld centerline are given in Figures 28 through 30.

Tables 1 and 2 present correction factors for the weld metal and plate metal respectively.

Table 3 shows the corrected maximum shearing, maximum principal, and minimum principal strains at all points as a function of percent applied load.

Table 4 shows the sum of strains measured with the separator gages for the various loads.

Photostress - Strain curves

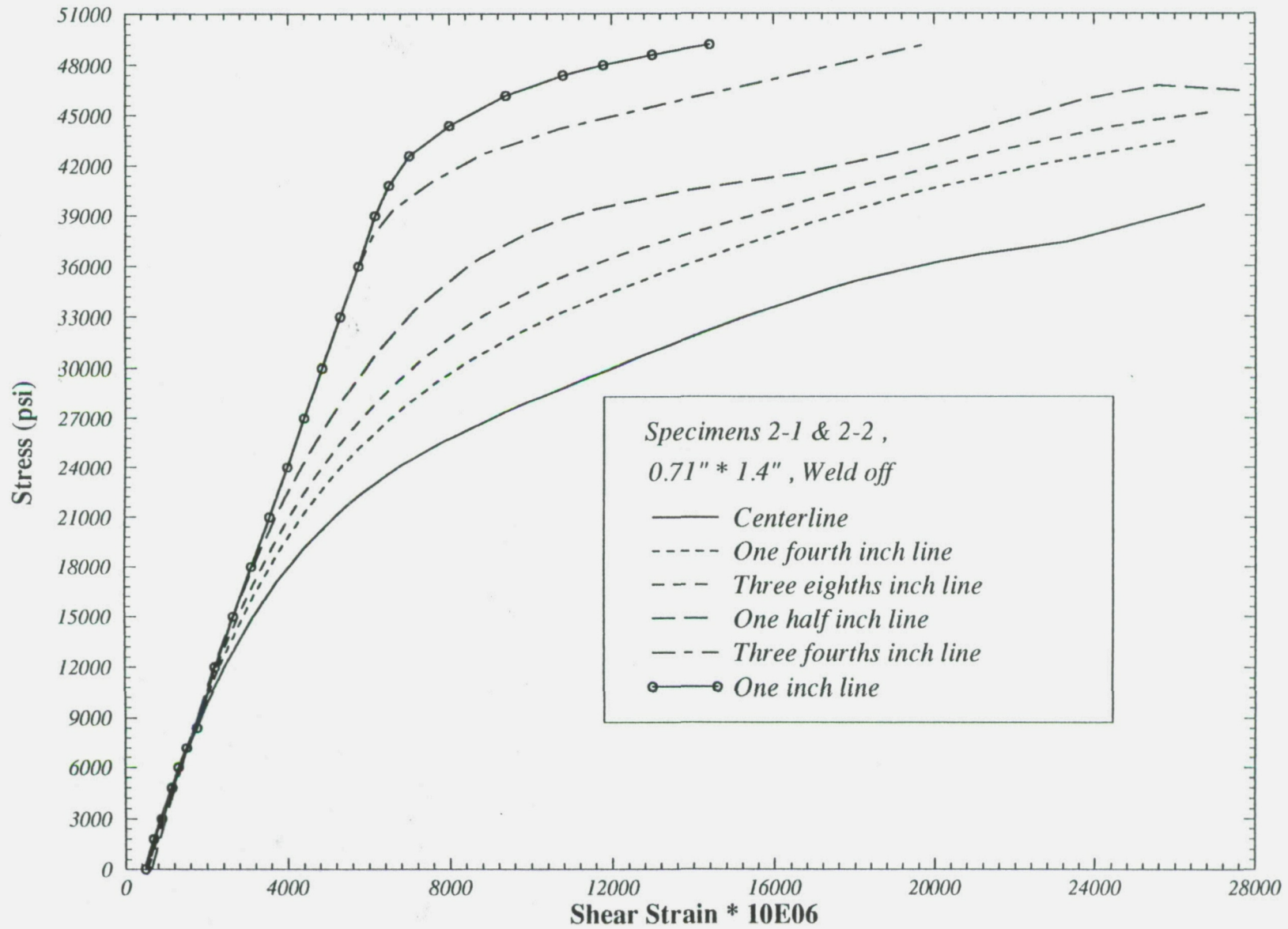


Figure 24. Photostress-Strain Curves, OD Side

Stress Vs Strain

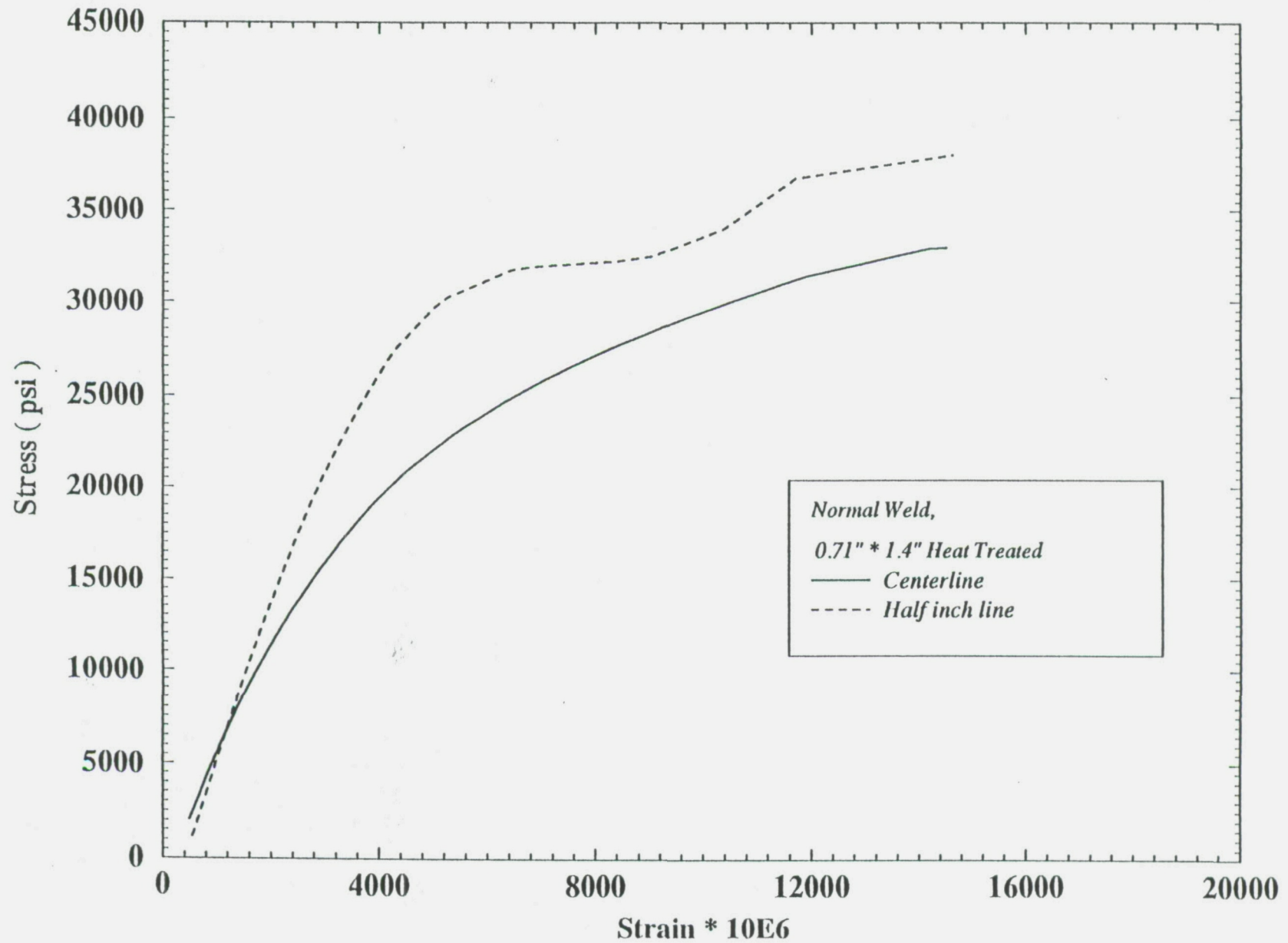


Figure 25. Stress-Strain Curves, OD Side

Stress Vs Contraction Ratio

Horizontal Centerline of Weld

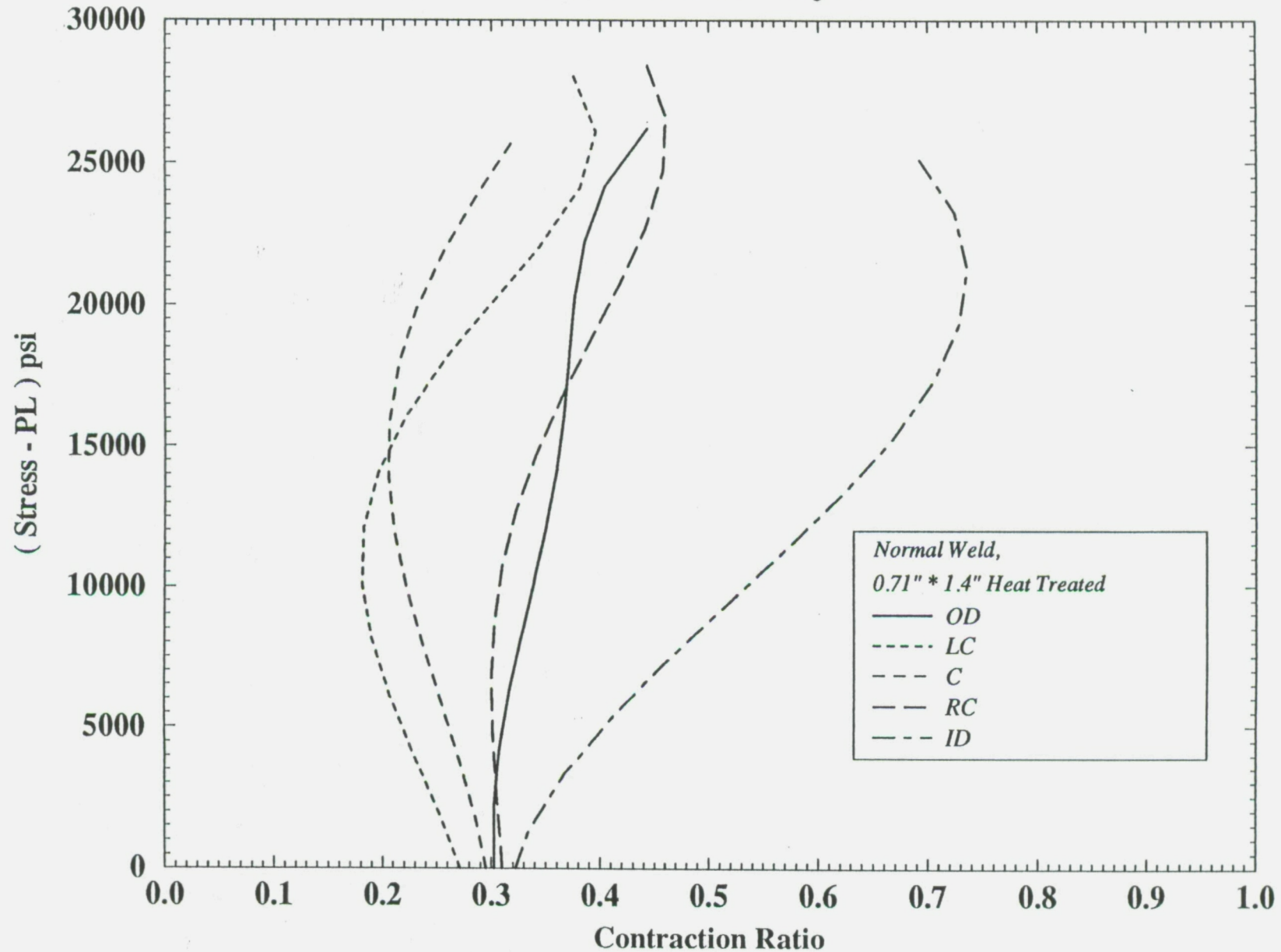


Figure 26. Contraction Ratio Curve for Weld, OD Side

Stress Vs Contraction Ratio

Horizontal Half Inch Line

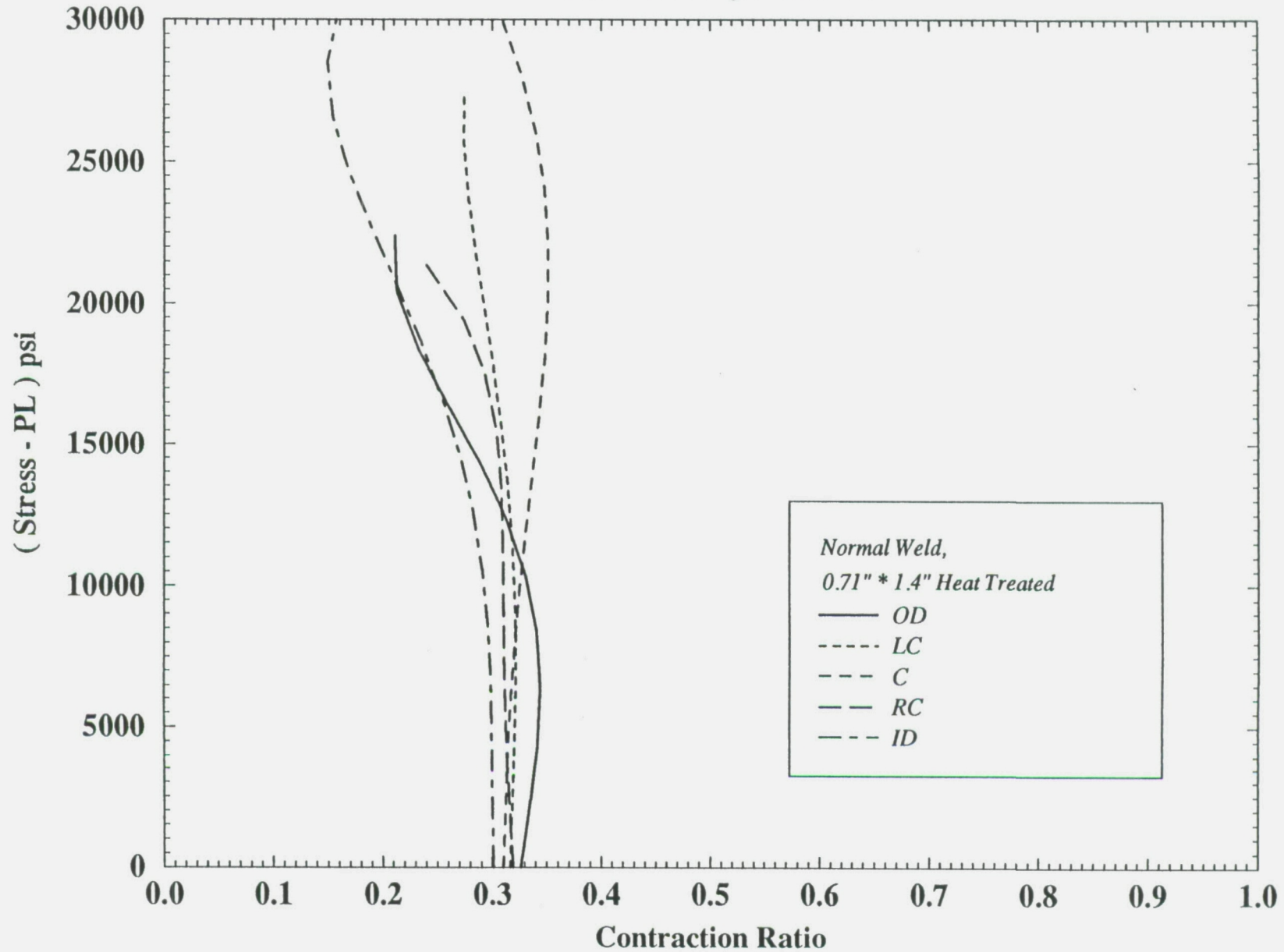


Figure 27. Contraction Ratio Curve for Plate, Half Inch Line, OD Side

Tangent Modulus Curves

From tensile stress - strain curves

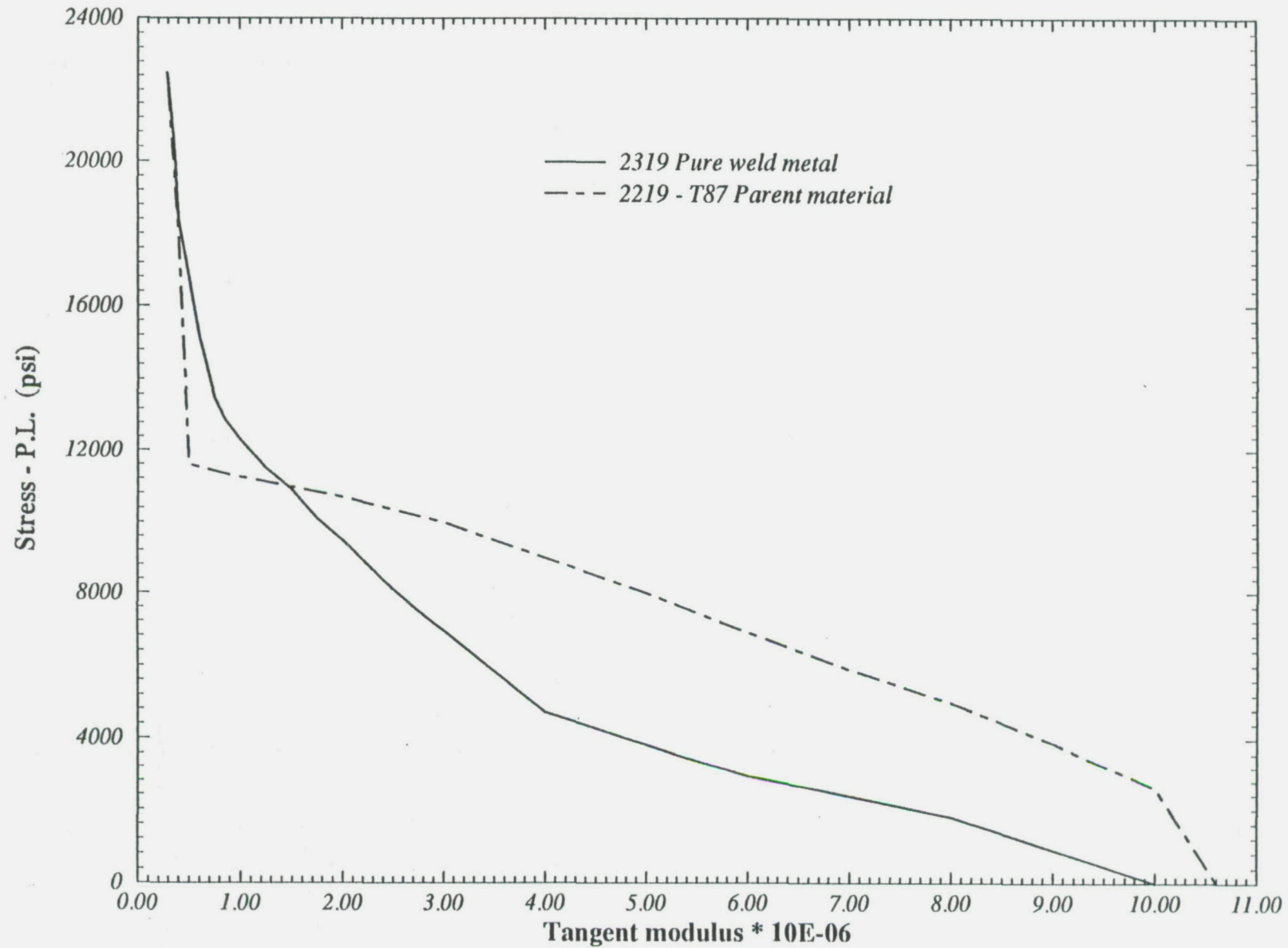


Figure 28. Tangent Modulus Curves, Pure Weld and Plate Metal

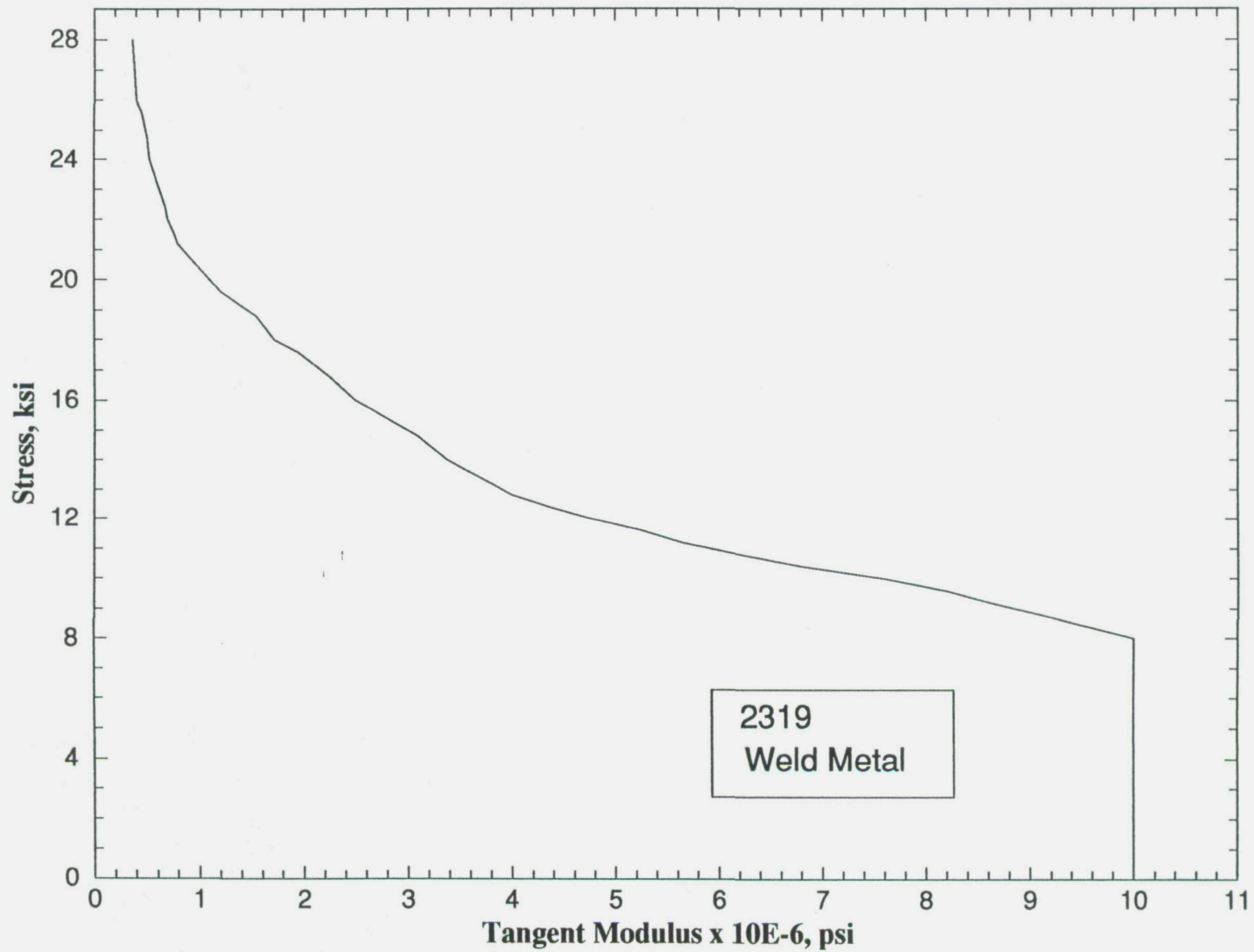


Figure 29. Tangent Modulus Curve for Joint, Weld Metal, OD Side

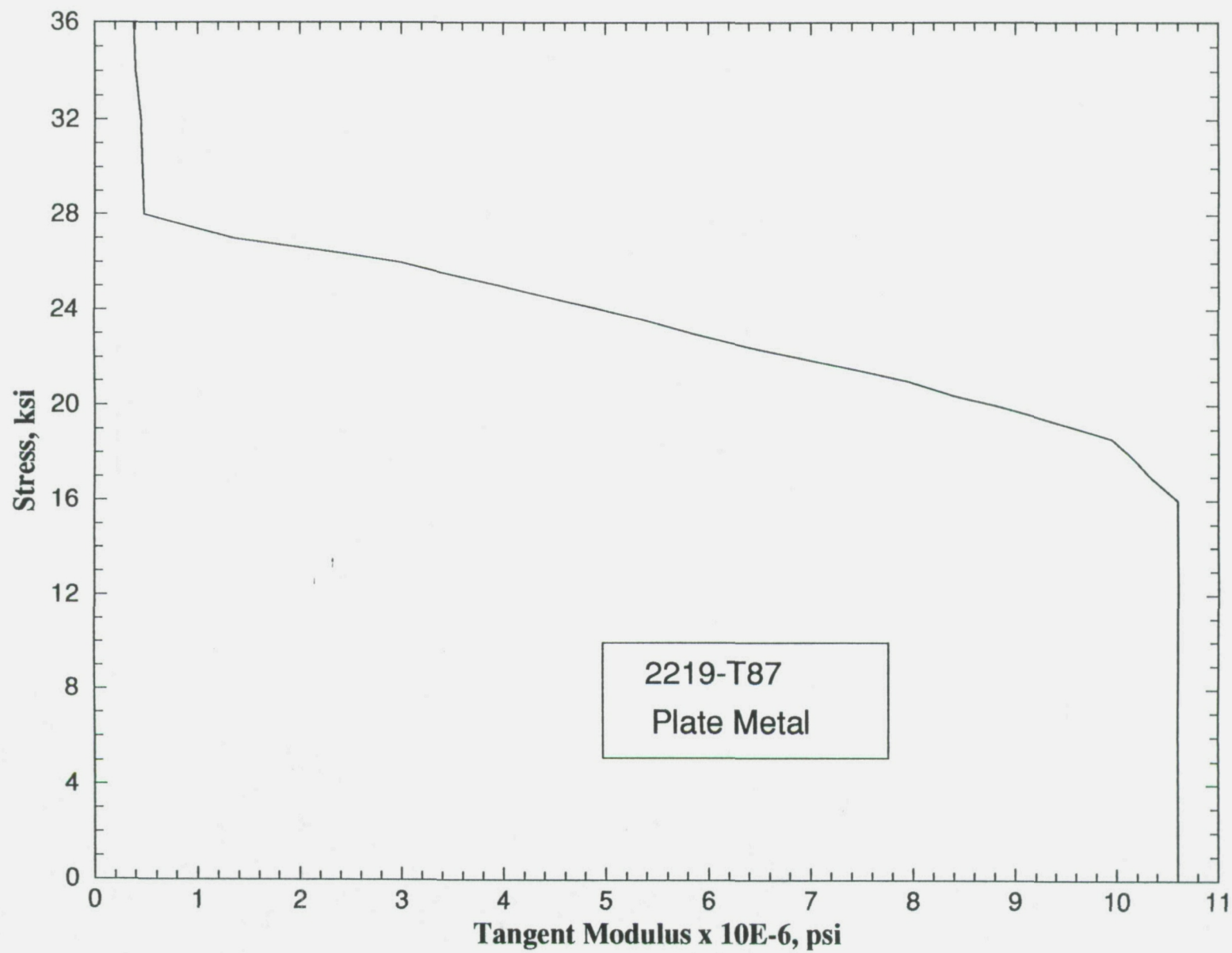


Figure 30. Tangent Modulus Curve for Joint, Plate Metal,
Half Inch Line, OD Side

Table 1

Weld Metal Correction Factors

Shear Strain $\times 10^6$	Tangent Modulus $\times 10^{-6}$	C_b	K_b
0-1600	10.00	0.963	0.920
1600-1950	9.10	0.964	0.922
1950-2300	7.10	0.966	0.925
2300-2700	5.00	0.971	0.929
2700-3150	3.30	0.982	0.940
3150-3650	2.90	0.983	0.940
3650-4150	2.40	0.989	0.946
4150-4750	2.10	0.994	0.950
4750-5450	1.50	1.010	0.965
5450-6250	1.02	1.030	0.989

Table 2

Plate and Forge Metal Correction Factors

Shear Strain $\times 10^6$	Tangent Modulus $\times 10^{-6}$	C_b	K_b
0-2250	10.60	0.963	0.921
2250-2850	10.38	0.963	0.921
2850-3100	9.95	0.963	0.921
3100-3420	8.90	0.964	0.923
3420-3750	7.50	0.966	0.924
3750-4100	6.10	0.968	0.927
4100-4500	4.60	0.973	0.931
4500-4920	3.25	0.980	0.938
4920-5450	1.30	1.017	0.973
5450-6100	0.46	1.131	1.080

Table 3
Corrected Strains $\times 10^6$

Percent Load

62

Point	Type Strain	5	14	20	28	42	56	70	TARE
1	γ ϵ_1 ϵ_2	0 — —	106 108 2	260 217 -43	568 468 -100	1396 1066 -330	1870 1479 -391	2809 2142 -666	231 175 -56
2	γ ϵ_1 ϵ_2	67 75 9	202 212 9	337 325 -12	732 665 -67	1502 1349 -153	2340 2053 -288	3126 2757 -369	376 399 24
3	γ	58	221	443	828	1502	2243	3116	231
4	γ ϵ_1 ϵ_2	58 66 8	231 212 -19	356 312 -45	693 590 -103	1377 1139 -238	2125 1756 -369	3034 2509 -525	289 342 53
5	γ	58	221	453	876	1581	2428	3382	260
6	γ	39	279	472	867	1851	2946	4145	492
7	γ	29	337	568	1021	1913	2946	4075	696
8	γ ϵ_1 ϵ_2	173 124 -50	376 298 -77	520 421 -99	1098 853 -245	1907 1483 -424	2764 2128 -636	3526 2733 -793	67 -3 -71
9	γ ϵ_1 ϵ_2	173 137 -36	385 363 -22	674 581 -93	1233 1072 -160	2070 1850 -220	2956 2634 -322	3911 3503 -407	10 0 -9
10	γ ϵ_1 ϵ_2	202 189 -14	501 481 -20	761 712 -49	1329 1263 -66	2350 2229 -120	3381 3178 -203	4340 4148 -191	144 146 1
11	γ ϵ_1 ϵ_2	154 197 43	491 503 12	770 740 -31	1290 1258 -33	2311 2219 -92	3191 3091 -100	4291 4147 -144	87 168 81
12	γ	58	289	404	693	1271	1907	2716	87
13	γ	29	202	289	645	1252	1868	2696	154
14	γ	67	241	395	751	1348	1926	2745	164
15	γ	58	221	424	722	1281	1868	2639	144
16	γ ϵ_1 ϵ_2	39 47 8	241 194 -47	347 275 -72	616 492 -124	1493 1064 -429	1849 1376 -473	2504 1851 -653	48 38 -10
17	γ ϵ_1 ϵ_1	10 23 14	231 180 -51	347 270 -77	664 526 -139	1406 1053 -353	1887 1464 -423	2552 1990 -562	29 37 9

Table 3, (Continued)
Corrected Strains $\times 10^6$

63

Percent Load

Point	Type Strain	5	14	20	28	42	56	70	TARE
18	γ	67	144	356	761	1425	1820	2475	58
	ϵ_1	57	141	284	583	1086	1449	1942	-13
	ϵ_2	-11	-3	-72	-178	-340	-371	-533	-70
19	γ	96	183	347	626	1242	1647	2109	10
20	γ	116	318	530	1050	1714	2282	3075	48
	ϵ_1	76	233	380	746	1244	1689	2234	-22
	ϵ_2	-39	-85	-150	-304	-470	-593	-841	-70
21	γ	87	337	539	1088	1695	2436	3008	0
	ϵ_1	71	279	435	866	1437	2052	2579	---
	ϵ_2	-16	-58	-104	-222	-258	-385	-429	---

Table 4
Strains From Separator Gages

Percent Load

Point	5	14	20	28	42	56	70	TARE
16	60	160	220	400	690	980	1300	30
8	80	240	350	660	1150	1620	2100	-80
20	40	160	250	480	840	1190	1510	-100
4	80	210	290	530	980	1500	2110	430
17	40	140	210	420	760	1130	1550	50
1	20	120	190	400	800	1180	1570	130
9	110	370	530	990	1770	2510	3340	-10
21	60	240	360	700	1280	1810	2330	-110
18	50	150	230	440	810	1170	1530	-90
2	90	240	340	650	1300	1900	2540	460
10	190	500	720	1300	2290	3220	4250	160
11	260	560	770	1330	2310	3240	4300	270